NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

REPORT No. 235 c. 3

INTERACTION BETWEEN AIR PROPELLERS AND AIRPLANE STRUCTURES

By W. F. DURAND

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1926

AERONAUTICAL SYMBOLS

1. FUNDAMENTAL AND DERIVED UNITS

	Symbol	Metric		English	
		Unit	Symbol	Unit	Symbol
Length	l	meter	m	foot (or mile)	ft. (or mi.).
Time	t	second	sec	second (or hour)	sec. (or hr.).
Force	F	weight of one kilogram	kg	weight of one pound	lb.
Power	P	kg/m/sec		horsepower	HP.
Speed		m/sec		mi./hr	M. P. H.

2. GENERAL SYMBOLS, ETC.

Weight, $W=mg$.

Standard acceleration of gravity, $g=9.80665 \text{m/sec}^2=32.1740 \text{ft./sec.}^2$

Mass, $m=\frac{W}{g}$

Density (mass per unit volume), ρ

Standard density of dry air, 0.12497 (kg-m^{-4}-sec^2) at 15°C and 760 mm=0.002378 (lb.-ft.^{-4}-sec.^2).

Specific weight of "standard" air, 1.2255 kg/m^3 =0.07651 lb./ft.^3

Moment of inertia, mk^2 (indicate axis of the radius of gyration, k, by proper subscript).

Area, S; wing area, S_w, etc.

Gap, G.

Span, b; chord length, c.

Aspect ratio $=b/c$.

Distance from $c.\ g.$ to elevator hinge, f.

Coefficient of viscosity, μ.

3. AERODYNAMICAL SYMBOLS

True airspeed, V.

Dynamic (or impact) pressure, $q=\frac{1}{2}\rho V^2$

Lift, L; absolute coefficient $C_L=\frac{L}{qS}$

Drag, D; absolute coefficient $C_D=\frac{D}{qS}$

Cross-wind force, C; absolute coefficient $C_c=\frac{C}{qS}$

Resultant force, R.

(Note that these coefficients are twice as large as the old coefficients L_c, D_c.)

Angle of setting of wings (relative to thrust line), i_w.

Angle of stabilizer setting with reference to thrust line, i_t.

Dihedral angle, γ.

Reynolds Number $=\rho\frac{Vl}{\mu}$ where l is a linear dimension.

e. g., for a model airfoil 3 in. chord, 100 mi./hr., normal pressure, 0°C: 255,000 and at 15°C, 230,000;

or for a model of 10 cm chord, 40 m/sec, corresponding numbers are 299,000 and 270,000.

Center of pressure coefficient (ratio of distance of $C.\ P.$ from leading edge to chord length), C_p.

Angle of stabilizer setting with reference to lower wing. $(i_t-i_w)=\beta$.

Angle of attack, α.

Angle of downwash, ϵ.

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By W. F. DURAND
Leland Stanford Junior University, California

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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INTERACTION BETWEEN AIR PROPELLERS AND AIRPLANE STRUCTURES

By W. F. Durand

INTRODUCTION

This investigation was conducted at the Leland Stanford Junior University by the National Advisory Committee for Aeronautics at the request of and with funds provided by the Army Air Service.

The purpose of the investigation, the results of which are presented in this report, was the determination of the character and amount of interaction between air propellers as usually mounted on airplanes and the adjacent parts of the airplane structure—or, more specifically, those parts of the airplane structure within the wash of the propeller, and capable of producing any significant effect on propeller performance.

In report No. 177, by Messrs. Lesley and Woods, such interaction between air propellers and certain simple geometrical forms was made the subject of investigation and report. The present investigation aims to carry this general study one stage further by substituting actual airplane structures for the simple geometrical forms.

From the point of view of the present investigation, the airplane structures, viewed as an obstruction in the wake of the propeller, must also be viewed as a necessary part of the airplane and not as an appendage which might be installed or removed at will.

ANALYSIS OF PROBLEM

In order to exhibit the quantities involved and their mutual relations, we may employ notation as follows:

Let R = resistance of entire airplane without propeller at speed V, and in horizontal unaccelerated flight. This is similar to the towed resistance used in similar problems in ship propulsion. It would be, in fact, the *towed* resistance if we could imagine the given airplane towed through still air at speed V.

Let the structure of the airplane be considered under three heads:

(1) The part under the influence of the propeller.

(2) A small or moderate amount of outlying structure, beyond that in the immediate wash of the propeller.

(3) The remainder of the airplane.

Let R_1 = resistance due to Part (1) without the propeller and at speed V.

R_2 = resistance due to Part (2) at speed V.

R_3 = resistance due to Part (3) at speed V.

Then $R = R_1 + R_2 + R_3$.

Let A = augmentation of resistance of Part (1) due to action of propeller.

T = thrust actually developed by propeller at air speed V and with a given value of V/nD and when operating in place on the airplane.

Then T is the total thrust actually developed by the airplane under operative conditions as above and we shall have

$$T = R_1 + A + R_2 + R_3 \text{ ----------------------------- } (1)$$

We may therefore view this total T as made up of two parts

$R_1+R_2+R_3$ = net or useful resistance overcome.

A = augmentation due to action of propeller on the airplane.

Obviously then, $T-A=R_1+R_2+R_3$ = useful resistance overcome .... (2)

Likewise

$$A=(R_1+R_2+R_3+A)-(R_1+R_2+R_3)$$

or

$$A=(R_1+R_2+A)-(R_1+R_2) \qquad (3)$$

Also $(T-A)\,V$ = useful power.

Let Q = torque.

Then $2\pi\,nQ$ = shaft or input power.

$$\text{Propulsive efficiency} = \eta_1 = \frac{(T-A)\,V}{2\pi\,nQ} \qquad (4)$$

This value compared with the value of η for the propeller operating in free air, and with the same value of V/nD, will then give a comparison between the propulsive efficiency and the free air efficiency for the same conditions of operation (same value of V/nD).

Suppose now a model to be made representing Parts (1) and (2) of the airplane—enough to surely include all parts of the airplane which can interact with the propeller and a little more for good measure. Then with this model and with the corresponding model propeller, let us assume a program of three series of tests as follows:

(1) Wind resistance tests of the model free.

(2) The usual tests of the propeller free, giving for a series of values of V/nD, values of thrust, torque and efficiency.

(3) Tests of the combination, including resistance measurements on the model and the usual measurements on the propeller, all carried out at a series of values of V/nD.

Then for any test under (3) there will be a resultant T with a certain V/nD and a certain V. This is obviously the actual thrust developed under operative conditions. The same test will give likewise a value of (R_1+R_2+A), the augmented resistance of the model. The preceding experiments will have given for the same V the value of (R_1+R_2) the normal free resistance. The difference will give the value of A, the augmentation due to the propeller, and this subtracted from the value of T will give the net or useful thrust realized. This is then used as indicated above, and the value of the propulsive efficiency thus found.

It will now be seen that the division of the structure of the airplane into three parts as above specified was for the purpose of indicating the possibility of eliminating Part (3) from the model and of thus limiting the latter simply to the Parts (1) and (2) as above noted. This makes possible the use of models of relatively large scale with the attendant advantage which such models give, and which are too well known to require special note.

Approaching the matter from a slightly different view point we reach the same result as follows:

Given the model and the propeller in operative relation. The propeller, under specified conditions, develops an actual thrust T. In so doing, however, it has increased the force reaction of the air on the model by the amount A. This amount A must then be deducted from T in order to find the net useful thrust developed for propulsive purposes—the thrust which is equal to the towed resistance of the airplane (complete structure) and which airplane such net thrust $(T-A)$ would serve to propel, could the operation be carried out without any interaction between airplane and propeller. The actual input power under these conditions is then the power which must be supplied to the propeller in order that, operating in front of the airplane, it will develop a total thrust T equal to the free resistance at the given speed plus the amount of augmentation which its operation entails.

From still another view point, suppose we imagine a propeller at the extremity of a shaft, say 1,000 feet long, extended out ahead of the airplane. We may then assume the interaction between the airplane and propeller negligible. Then both propeller and airplane will operate as

in free air and the resistance of the latter will be the free air or "towed" resistance as referred to above. Obviously, the propulsive efficiency here will be the same as the propeller efficiency in free air. If then we imagine the shaft to be gradually shortened in, there will begin to develop, in due time, an interaction between the airplane and the propeller, as a result of which both the thrust (pull) developed and the resistance to be overcome will increase. Finally with the propeller in its normal relation to the airplane we shall find a notable increase in both, and if the engine is driven at such speed as will serve to give the same airspeed of the airplane as before, we may consider that the same net useful result is accomplished. This useful power will evidently be $(T-A)\,V$ and the input power to accomplish this will be $2\pi nQ$—the power resulting from the actual n and actual Q. The ratio between the two will then give the propulsive efficiency under the given conditions of operation.

A physical cause for the augment of wind reaction or force on the airplane is found in the augment of velocity of the air in the propeller wash and which flows against the front of the model.

Likewise, a physical cause for the augment of thrust (pull) developed by the propeller is found in the slowing down of the air velocity as it approaches the propeller and in consequence of the obstruction represented by the airplane. With a given value of n, the thrust increases as the airspeed decreases and in consequence, if the central column of air approaching the propeller is slowed down relative to its velocity in the case of the propeller free, the latter will show a corresponding augment of thrust developed.

Certain aspects of the phenomena as observed in the tests covered by the present report suggest that there are other conditions which must be included in order to obtain a complete account of these changes in air reaction and in thrust. At the present time, however, data are not available for any further statement regarding the matter.

MODELS EMPLOYED

In order to realize the purposes as above indicated, three models were constructed as follows:

Model A represents a part of a thick wing section under study by the Army Air Service with reference to its availability for use in a new type of bombing airplane. This model is shown in Figures 1 and 2.

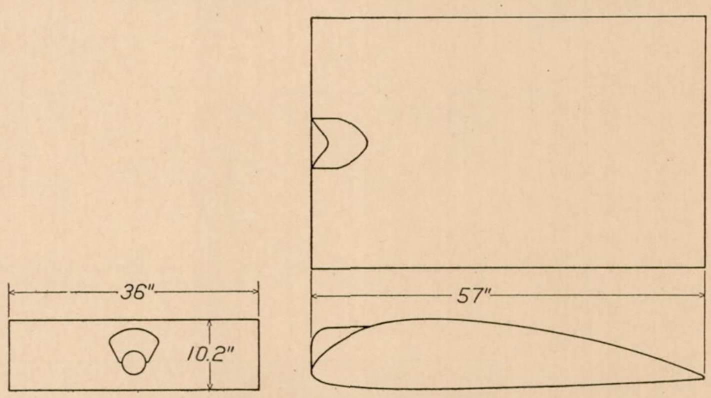

FIG. 1.—Night bomber, type XIII. Model A. Stanford University. (See Drawing M–2102, Air Engineering Division U. S. A.

The throat diameter of the wind tunnel at Stanford University is 90 inches and having in view the maximum over-all size of model which it seemed wise to use in a tunnel of this size, it developed that, with the propellers in proportionate size, a diameter of 24 inches was indicated. Accordingly the propellers were made of this diameter, and the model of proportionate size, the wing section of the model extending 6 inches beyond the tip of the blades, and thus having an over-all breadth of 36 inches.

Model B represents the central power plant installation of the same design as for model A. This model is shown in Figures 3 and 4. The more immediate obstruction in the case of model B is represented by the machine gun turret immediately back of the propeller, by the landing gear a little farther away, and by the wings at a still greater distance. In the case of this model, with the front edges of the wing so far back of the propeller, it was not convenient to carry the wing back the distance of its entire chord. It was therefore carried back in regular form for a part of the way, and then faired down to the trailing edge more abruptly than in the actual design. See dotted lines of Figure 3. This gives a wing of shortened chord as

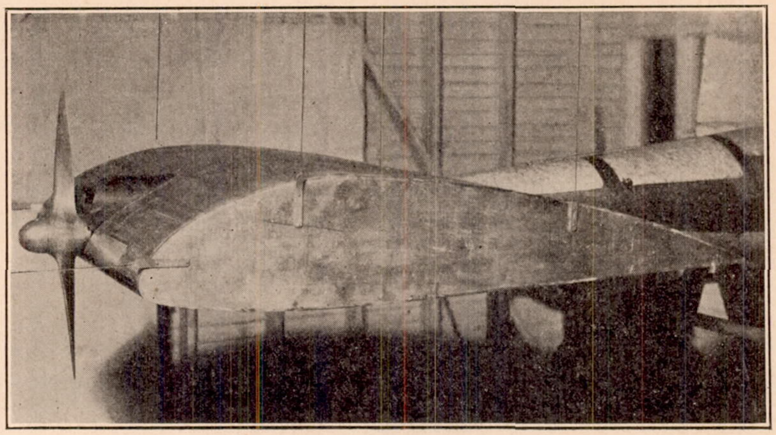

FIG 2.—Model A

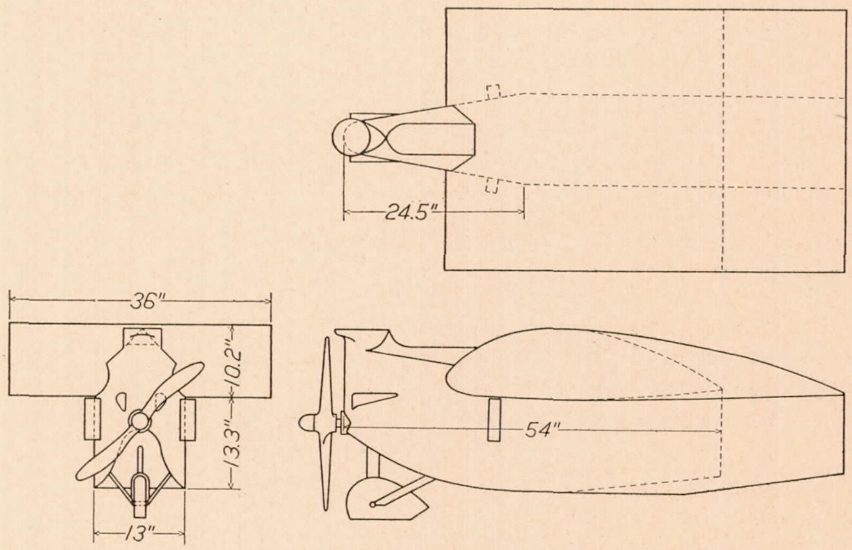

FIG. 3.—Night bomber, type XIII. Model B. Stanford University. (See drawing M-2102, Air Engineering Division U. S. A.)

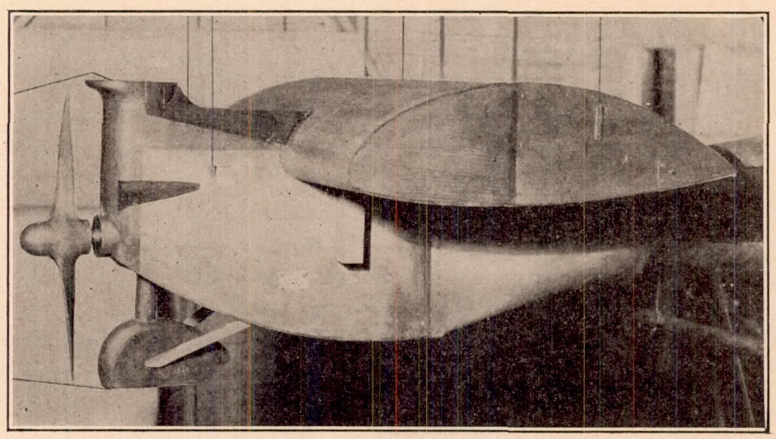

FIG. 4.—Model B

compared with the regular wing of model A. Experience with the character of the reaction between the propeller and the adjacent parts of the structure, and especially with the parts which are most influential in producing such reaction, gives good ground for the belief that such a shortening up of the chord, with the wing as far removed as it is, will have no important influence on the results so far as the propeller is concerned. The aerodynamic properties of the wing would of course be different in themselves, but it is not here a question of the aerodynamic properties in themselves, but rather of the *difference* in such properties produced by the propeller, and of the *difference* in the performance of the propeller produced by the proximity of these structural elements.

Model C represents the front end of the fuselage of the DeHavilland airplane as shown in Figures 5 and 6. In this case, having in view the distance between the propeller and the wings, and in order to simplify the construction of the model, it was decided to omit the wings entirely. While therefore the model does not represent all parts of the airplane within the wash of the propeller, all previous tests with obstructions indicate that in such a design the reaction between airplane and propeller must in preponderant degree be due to the nose of the fuselage rather than to the wings and tail surfaces. The nose of the model was fitted with a wire mesh, 40 spaces per inch, and wire 0.006 inch diameter. This is found to have an air resistance closely comparable to that of an airplane radiator of normal design. In addition and for comparative purposes, the model was also run with the end entirely open, and also blanked off with a sheet of heavy paper.

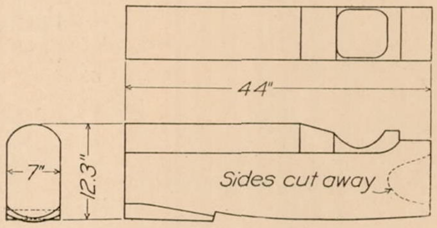

FIG. 5.—DH4 fuselage. Model C. Stanford University. (Fuselage shortened to accommodate dynamometer)

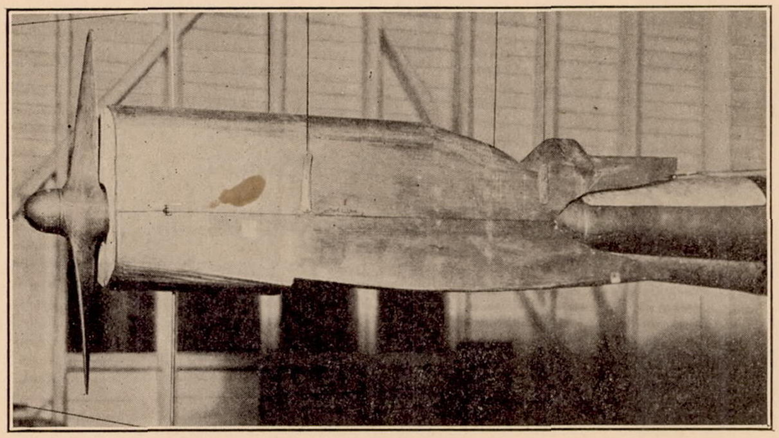

FIG. 6.—Model C

Regarding the lack of complete similarity between airplane and model, or more particularly in models B and C it may be noted that with the construction and set-up of the dynamometer, this was unavoidable. However, a very considerable body of observation with geometrical models as well as the results of the present investigation with different values of the clearance all go to show the very rapid falling off of influence on the propeller with increase of distance between the propeller and the obstructing surface or body. These results all tend to support definitely the conclusion that the influence of surfaces giving generally a frictional drag and at distances of one and one-half diameters of the propeller or more, would produce an effect on the propeller presumably within the error of observation.

Propellers.—The propellers employed were two in number, similar to Nos. 7 and 3 of Report No. 141, and of which the principal characteristics are as follows:

Propeller No. 1, pitch ratio, 0.7.
Propeller No. 2, pitch ratio, 0.9.
Diameter, 24 inches.
Mean blade width, 0.15 *r*.
Maximum blade width, 0.18 *r*.

The blade shape (developed) and the forms of sections at radii 2.67, 4.67, 6.67, 8.67, 10.67 inches are shown in Figure 7.

The propellers are similar in all respects except as to pitch ratio. The face pitch is uniform.

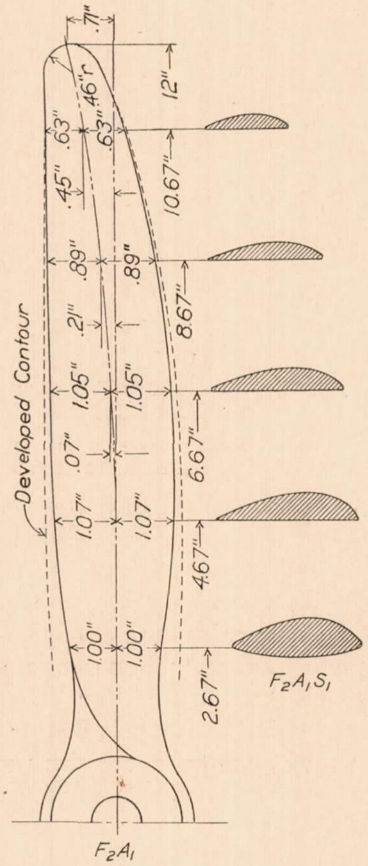

FIG. 7.—Plan form and section of propellers with .7 and .9. p/D

NUMBER OF COMBINATIONS OF SIGNIFICANT ELEMENTS

In the case of models A and B, each model was tested with each propeller and for each of three values of the distance or clearance between the propeller blades and the nearest part of the model. In the case of model C, tests were made with each propeller at each of two values of the distance or clearance between the propeller blades and the fuselage nose, and for each of three conditions or degrees of nose obstruction.

This gives 12 different set-ups with models A and B and 12 with model C, or 24 in all.

SET-UP OF APPARATUS AND MODEL

It may be proper to recall, at this point, that the wind tunnel at Stanford University is of the Eiffel type and with principal dimensions as indicated in Figure 8.

The dynamometer, as indicated in Figure 9, consists essentially of a slender tapering barrel some 9 feet long mounted on knife-edges as a cradle dynamometer and with the model propeller motor located in the larger down-wind end of the barrel, faired in as a part of the barrel form. The motor is connected to the propeller through a special form of drive which transmits torque with longitudinal freedom of propeller shaft. This general arrangement provides for the direct measurement of thrust and torque which are weighed on beam scales, graduated, respectively, in hundredths of kilograms and in thousandths of kilogram-meters.

In order to provide for the independent measure of forces on the propeller model and on the airplane model, the latter was suspended by piano wires from the ceiling of the experiment chamber, the length of suspension being about 7 feet. The model, thus suspended, hangs entirely free of contact with the dynamometer barrel and may be placed in any desired clearance relation with the propeller. This arrangement places the model and the propeller in operative relation geometrically while permitting of independent measure of the forces on each. This arrangement is shown in Figures 2, 4, and 6.

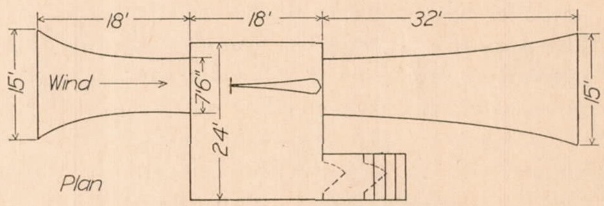

FIG. 8.—Wind tunnel of Stanford University (approximate sketch)

For the direct measurement of air forces on the model a piano-wire bridle was attached to the two sides of the model at shaft level and thus accommodating the propeller between the two sides of the bridle leads. From the apex of the triangle thus formed a single piano wire was led forward (up wind) through the honeycomb baffle, through and beyond the tunnel inlet to the end wall of the building, and over a carefully fitted-up pulley down to a gross weight on the plate of a beam scale weighing to hundredths of a pound. Thus, by subtraction, the pull on the model due to air flow may be directly weighed on the scale.

In order, however, that the reading of the scale may be made to indicate air forces and nothing else, it is necessary that the model, when in the observing condition, should hang in the free gravity position; otherwise there will be a gravity component, plus or minus, included

in the scale reading. In order to eliminate any such component, the following operative routine was followed:

The model, without wind and disconnected from the piano wire leading to the scale, was allowed to hang freely under gravity and while so hanging a transit instrument, set up abreast of the model and at the side of the experiment chamber, entirely out of the wind stream, was adjusted with vertical cross hair on a reference mark on a paper scale attached to the model. Then, during the observations, the model was brought, by suitable fine motion adjustment, exactly to this initial or zero position, with the mark on the vertical cross hair. Under these conditions the scale readings may be properly interpreted as giving (by subtraction from the gross) the actual wind forces on the model.

It is obvious, furthermore, that this arrangement may be used either with or without the propeller, and thus provide for a measurement of air forces on the model either in a homogeneous air stream or as influenced by the operation of the propeller placed with any desired clearance between itself and the forward edge or plane of the model.

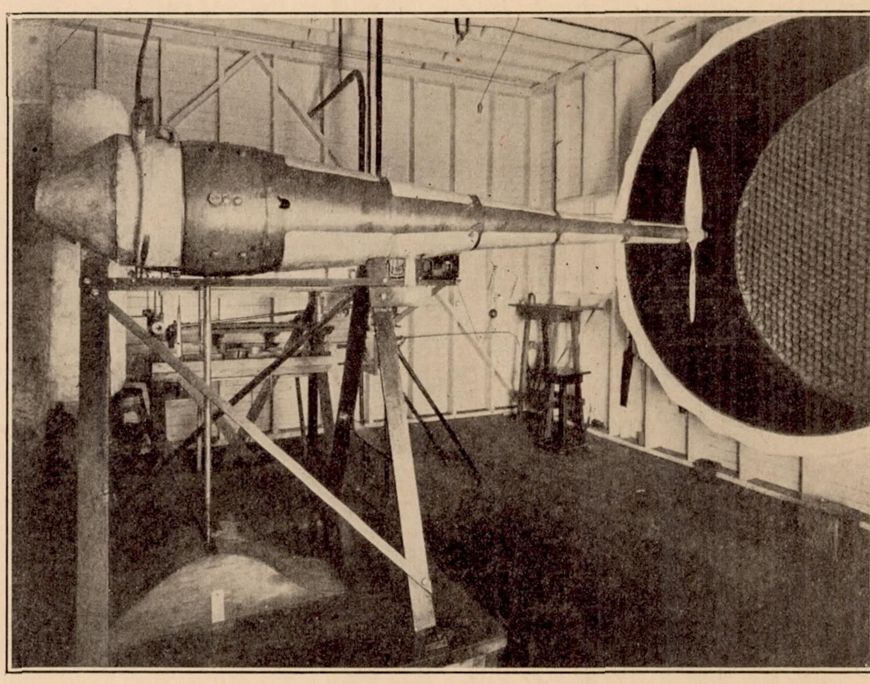

FIG. 9.—General view of dynamometer

OBSERVATIONS

In accordance with the methods indicated in the preceding sections observations were made covering the various elements of the problem. These observations with the resulting values of the various coefficients are given in Tables III to XXVI.

In the reduction of these observations the following coefficients have been employed:

C_T = Thrust coef. (propeller alone) $= \dfrac{T}{\rho n^2 D^4}$.

C_T = Thrust coef. (propeller with airplane)* $= \dfrac{(T-A)}{\rho n^2 D^4}$.

C_{P_1} = Power Coef. $= \dfrac{P}{\rho n^3 D^5}$.

η = Efficiency (propeller alone).

η_1 = Propulsive efficiency (propeller with airplane) $= \dfrac{C_T}{C_{P_1}} \dfrac{V}{nD}$.

Also for tabular presentation, the following notation is convenient.

T = Actual thrust.

R_a = Resistance of model with propeller in action.

R_o = Resistance of model without propeller, at same speed as for R_a.

A = Augment of resistance due to propeller $= R_a - R_o$.

C_T = Thrust coef. $= (T-A) \div \rho n^2 D^4$.

C_{P_1} = Power coef. $= P \div \rho n^3 D^5$.

* No confusion seems to result from the use of the same symbol C_T for thrust coefficient either with or without airplane. The context will always indicate which condition obtains. When $A=0$ the two values become identical.

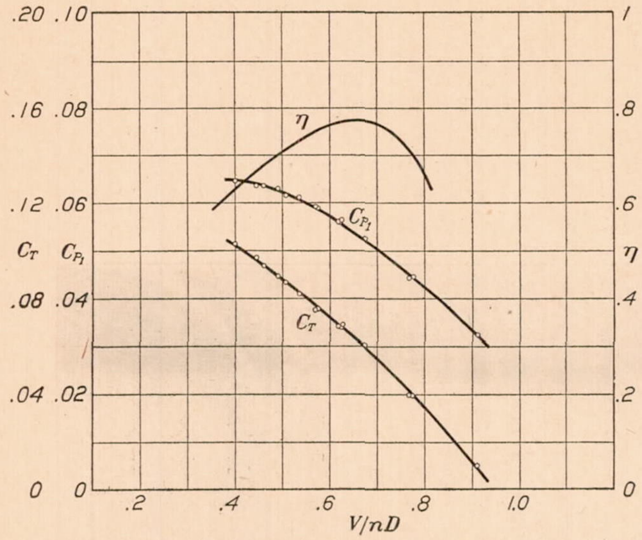

FIG. 10.—Characteristic coefficients of propeller No. 7. Diameter 24 inches. Nominal pitch ratio .7

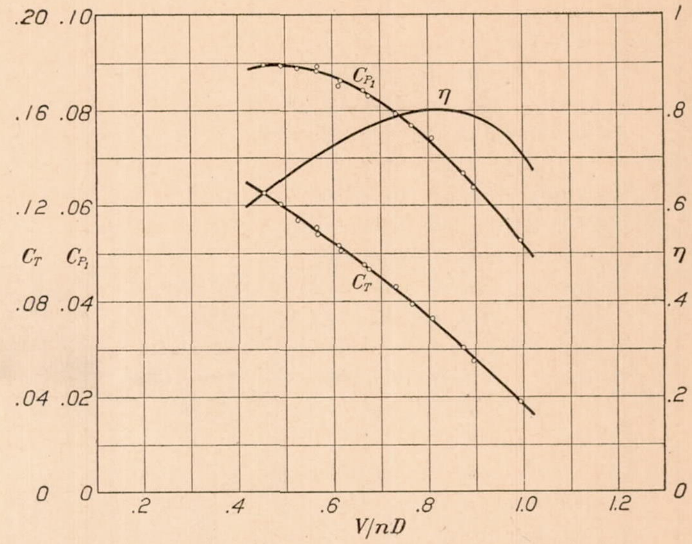

FIG. 11.—Characteristic coefficients of propeller No. 2. Diameter 24 inches. Nominal pitch ratio 9.

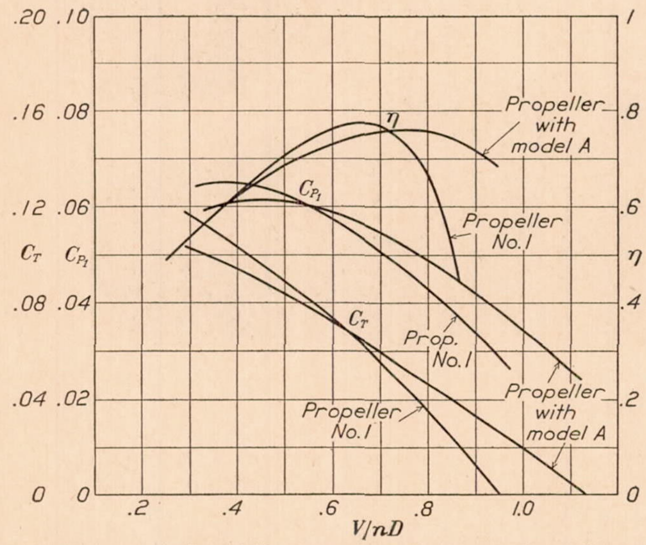

FIG. 12.—Typical effect of slip stream obstruction on propeller coefficients. Propeller No. 1. Unobstructed. Propeller No. 1 with model A at 4 inch clearance

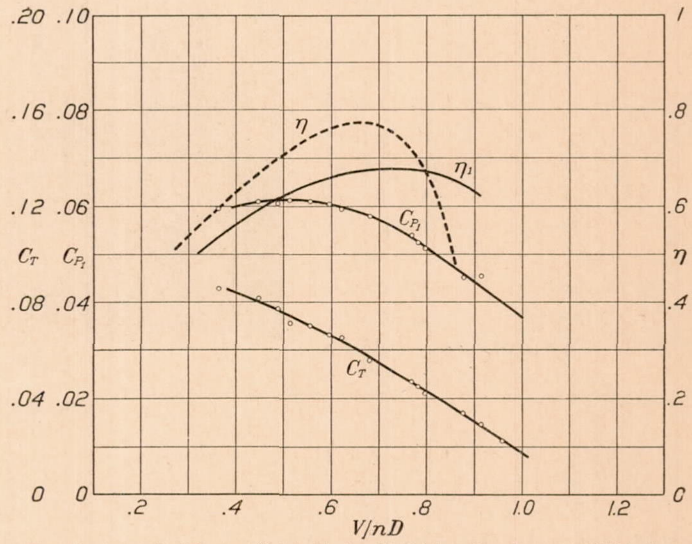

FIG. 13.—Propeller No. 1. Pitch ratio .7. Model A—wing clearance 0.375 inches

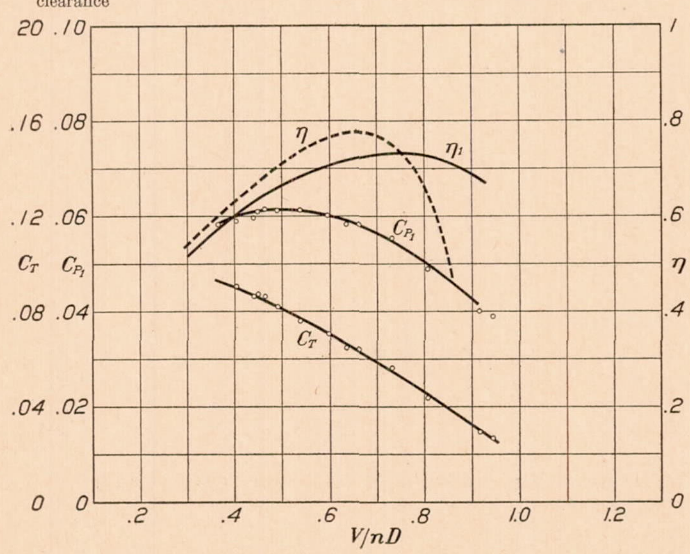

FIG. 14.—Propeller No. 1. Pitch ratio .7. Model 1—wing clearance 2 inches

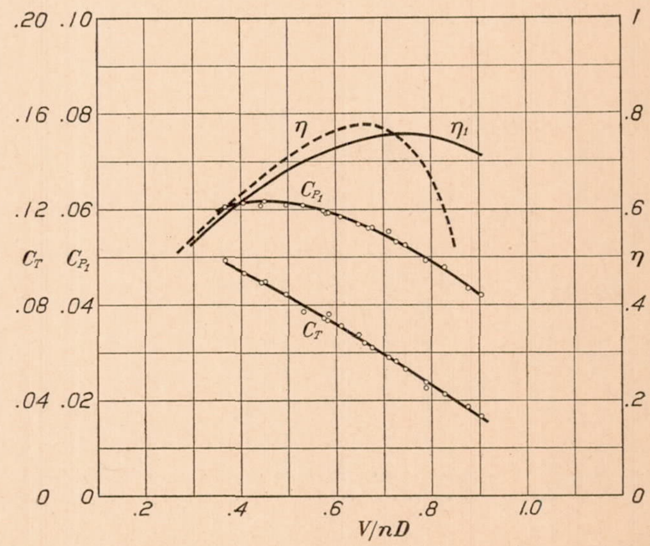

FIG. 15.—Propeller No. 1. Pitch ratio .7. Model A—wing clearance 4 inches

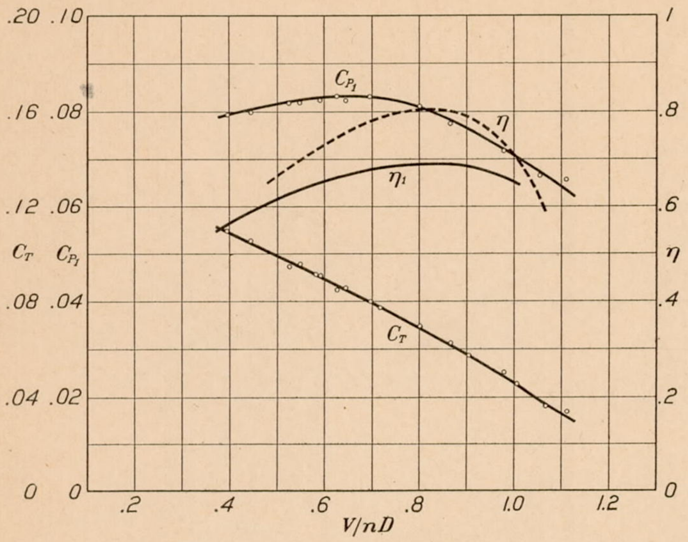

FIG. 16.—Propeller No. 2. Pitch ratio .9. Model A—wing clearance 0.375 inches

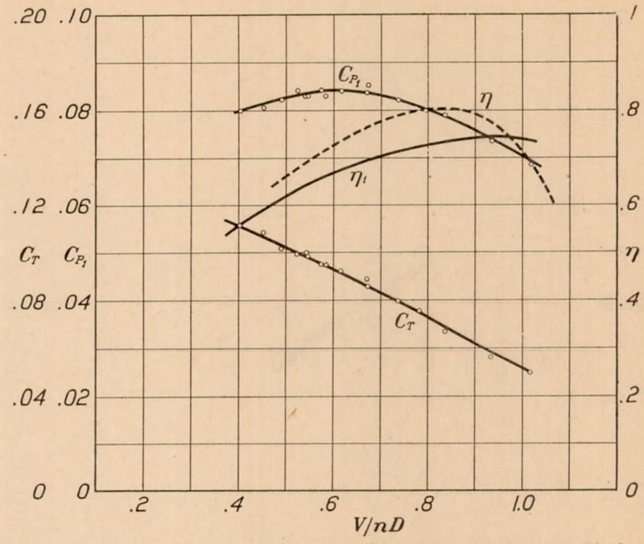

FIG. 17.—Propeller No. 2. Pitch ratio 9. Model A—wing clearance 2 inches

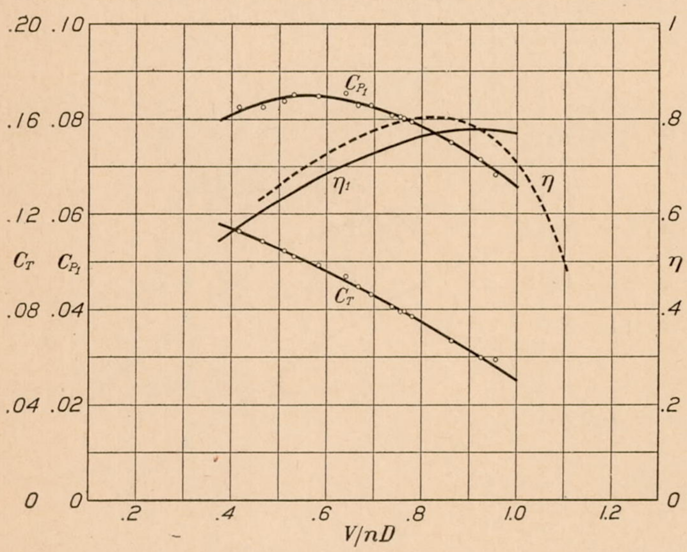

FIG. 18.—Propeller No. 2. Pitch ratio .9. Model A—wing clearance 4 inches

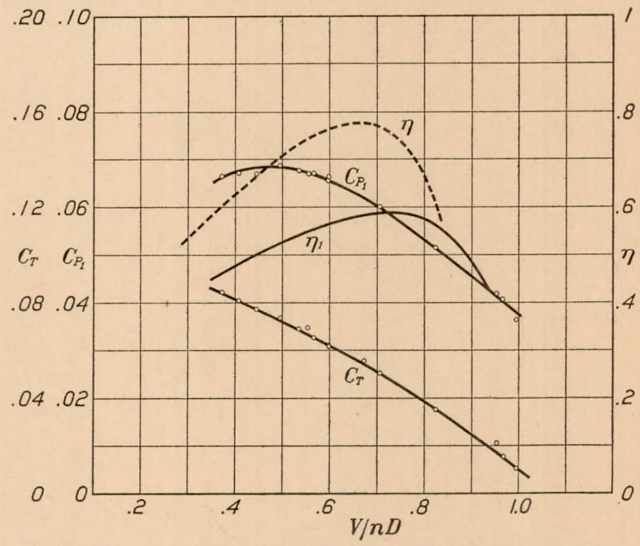

FIG. 19.—Propeller No. 1. Pitch ratio .7. Model B—fuselage clearance 0.375 inches

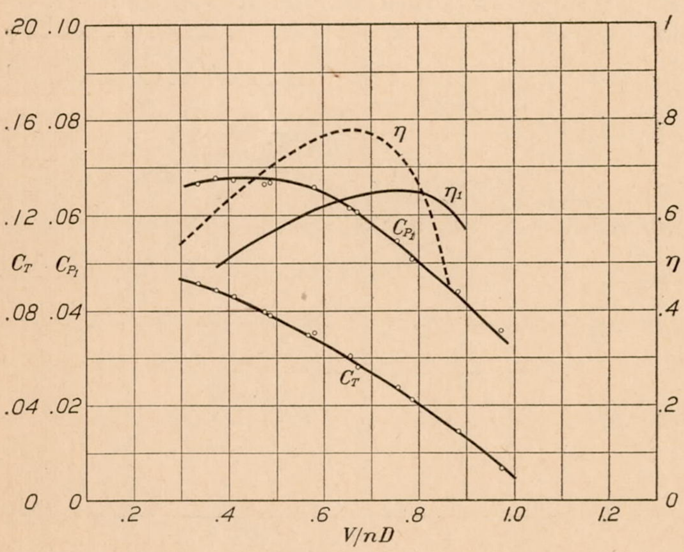

FIG. 20.—Propeller No. 1. Pitch ratio .7. Model B—fuselage clearance 2 inches

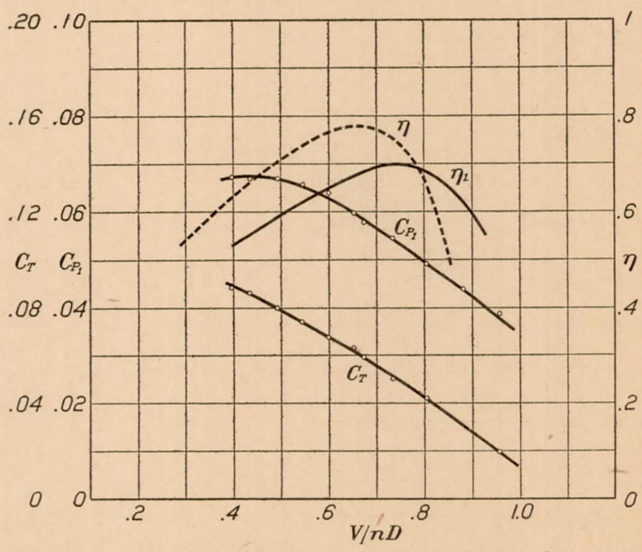

FIG. 21.—Propeller No. 1. Pitch ratio .7. Model B—fuselage clearance 4 inches

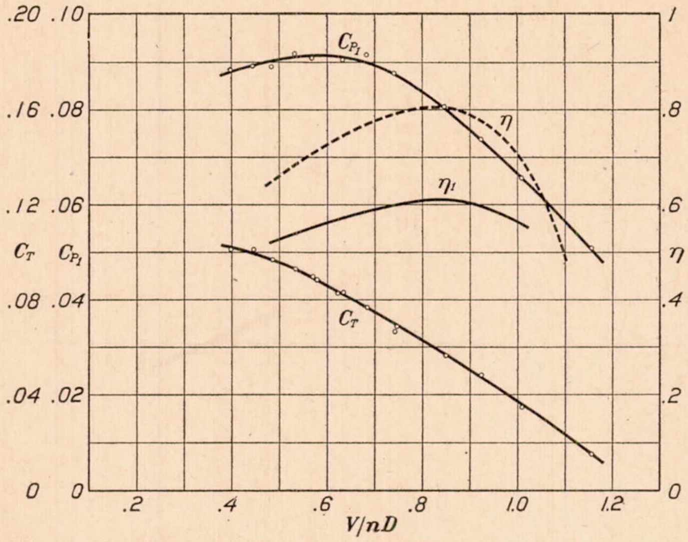

FIG. 22.—Propeller No. 2. Pitch ratio .9. Model B—fuselage clearance 0.375 inches

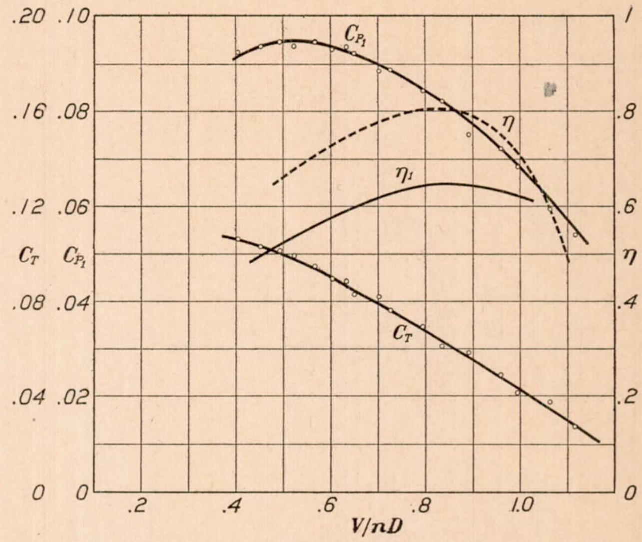

FIG. 23.—Propeller No. 2. Pitch ratio .9. Model B—fuselage clearance 2 inches

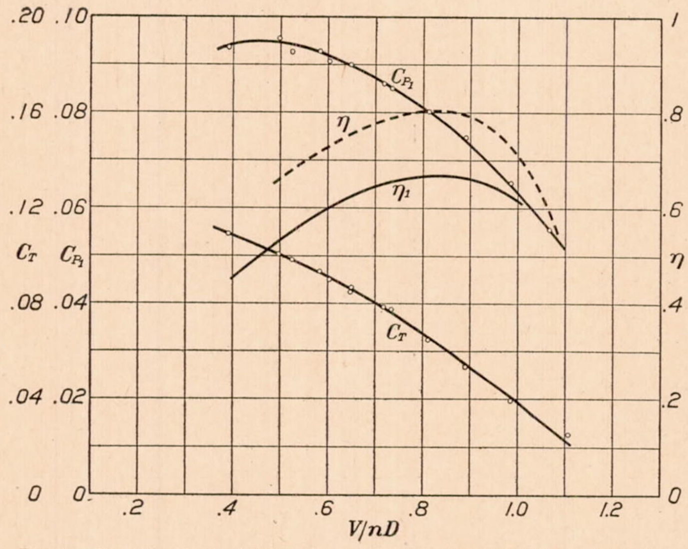

FIG. 24.—Propeller No. 2. Pitch ratio .9. Model B—fuselage clearance 4 inches

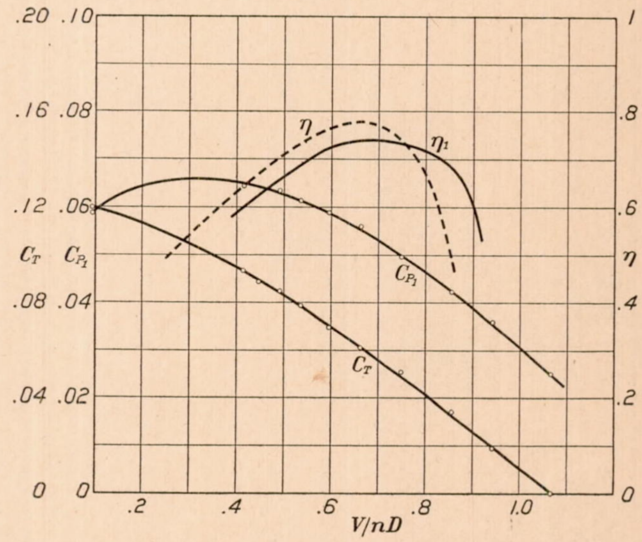

FIG. 25.—Propeller No. 1. Pitch ratio .7. Model C—DeHavilland. Clearance 0.375 inches. Radiator, wire gauze

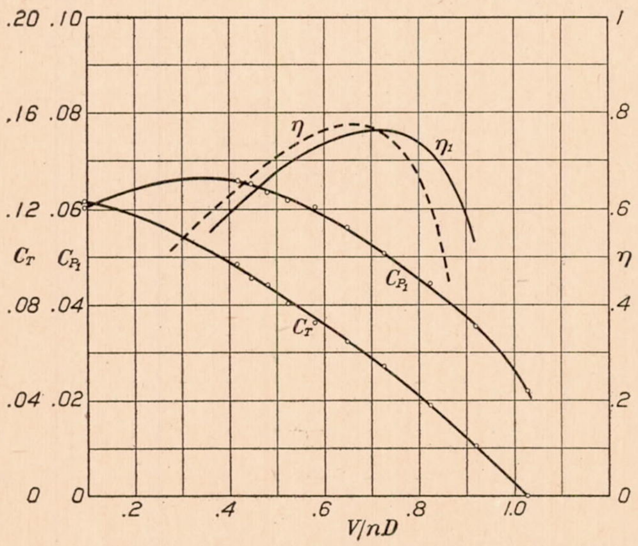

FIG. 26.—Propeller No. 1. Pitch ratio .7. Model C—DeHavilland. Clearance 4 inches. Radiator, wire gauze

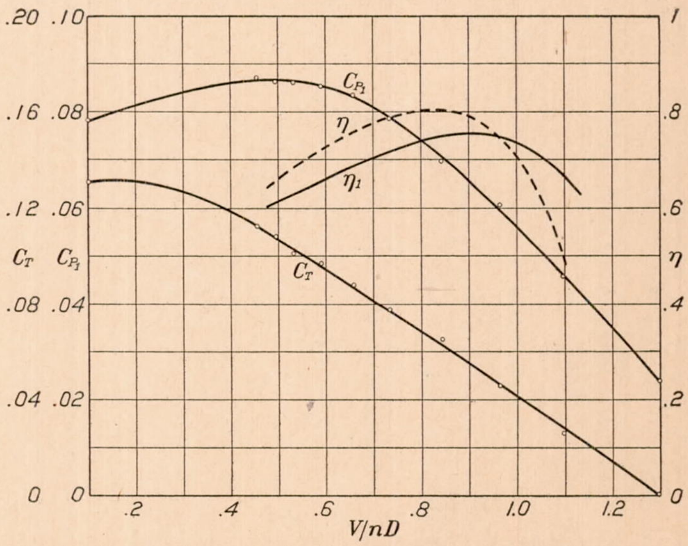

FIG. 27.—Propeller No. 2. Pitch ratio .9. Model C—DeHavilland. Clearanec 0.375 inches. Radiator, wire gauze

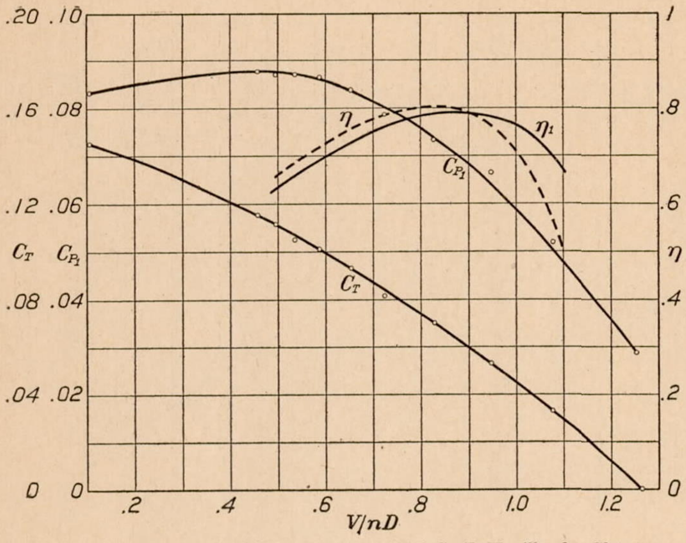

FIG. 28.—Propeller No. 2. Pitch ratio .9. Model C—DeHavilland. Clearance 4 inches. Radiator, wire gauze

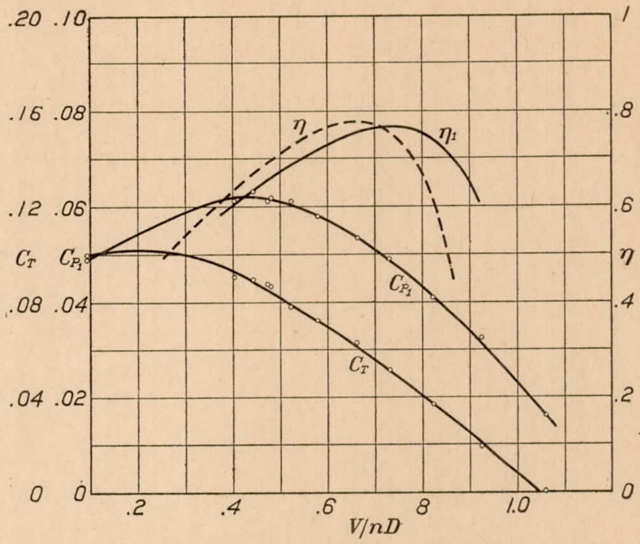

FIG. 29.—Propeller No. 1. Pitch ratio .7. Model C—DeHavilland. Clearance 0.375 inches. Radator, space open

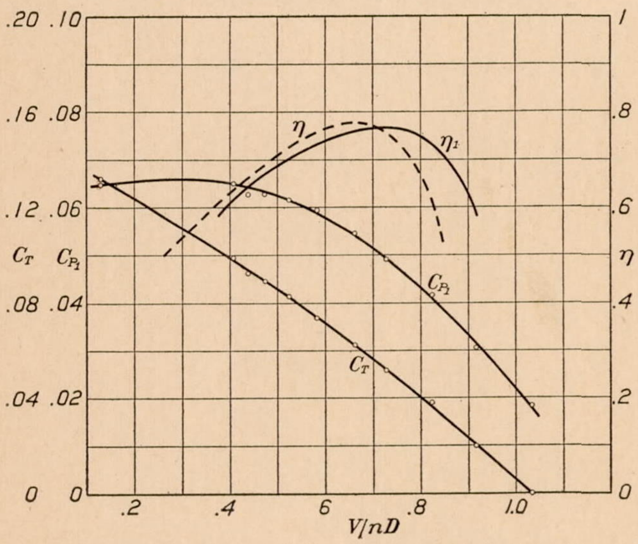

FIG. 30.—Propeller No. 1. Pitch ratio .7. Model C—DeHavilland. Clearance 4 inches. Radiator, space open

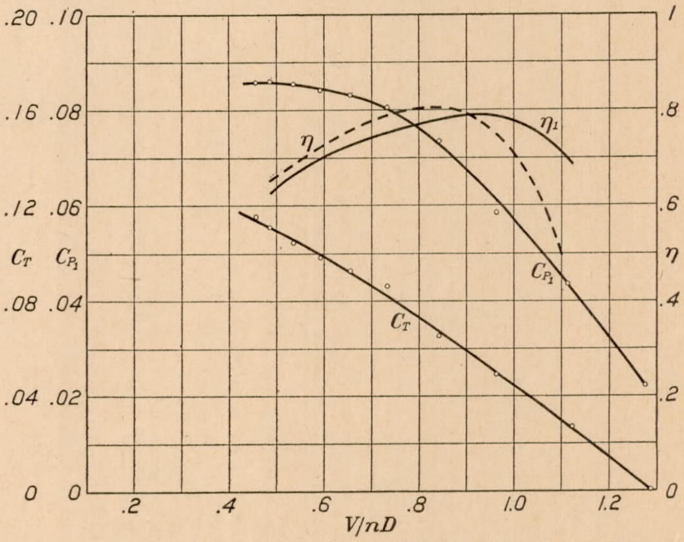

FIG. 31.—Propeller No. 2. Pitch ratio .9. Model C—DeHavilland. Clearance 0.375 inches. Radiator, space open

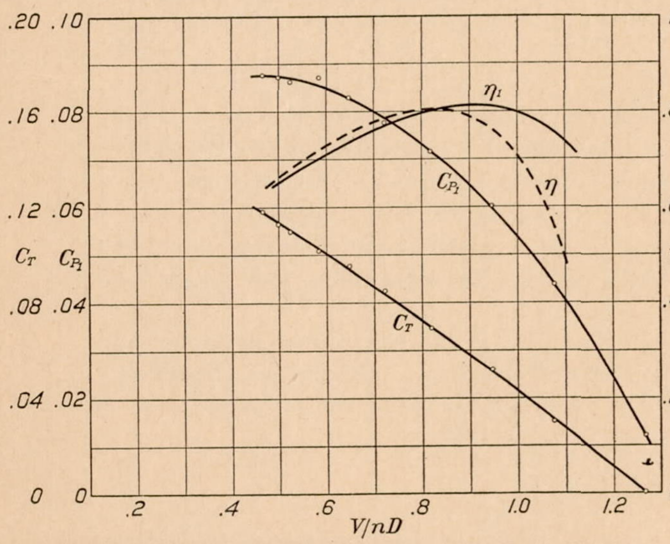

FIG. 32.—Propeller No. 2. Pitch ratio .9. Model C—DeHavilland. Clearance 4 inches. Radiator, space open

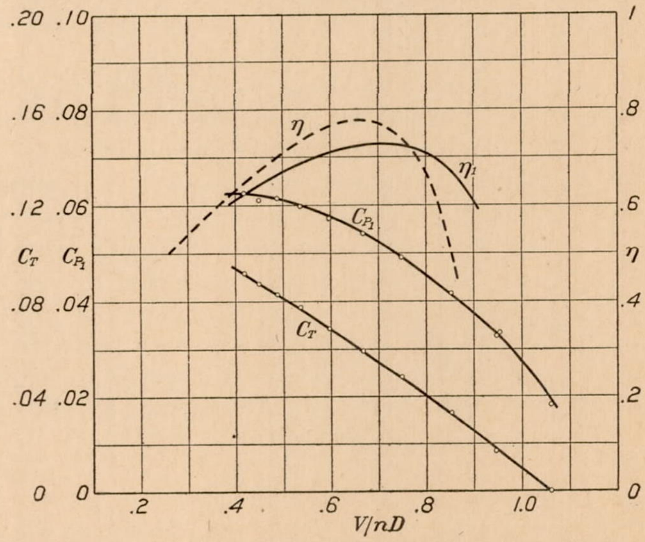

FIG. 33.—Propeller No. 1. Pitch ratio .7. Model C—DeHavilland. Clearance 0.375 inches. Radiator, closed

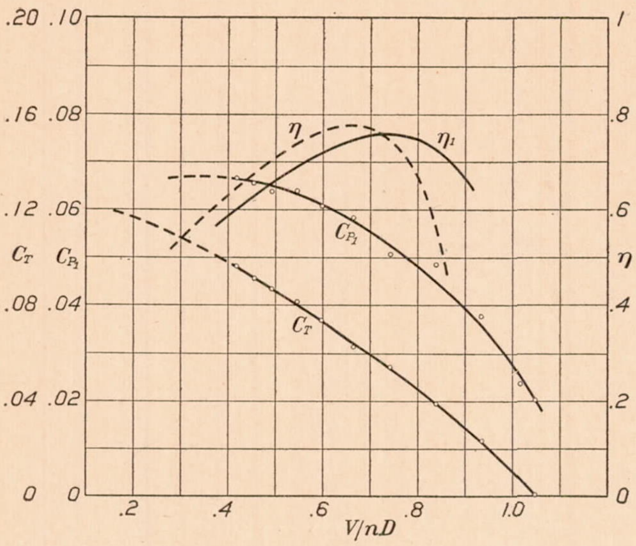

FIG. 34.—Propeller No. 1. Pitch ratio .7. Model C—DeHavilland. Clearance 4 inches. Radiator, closed

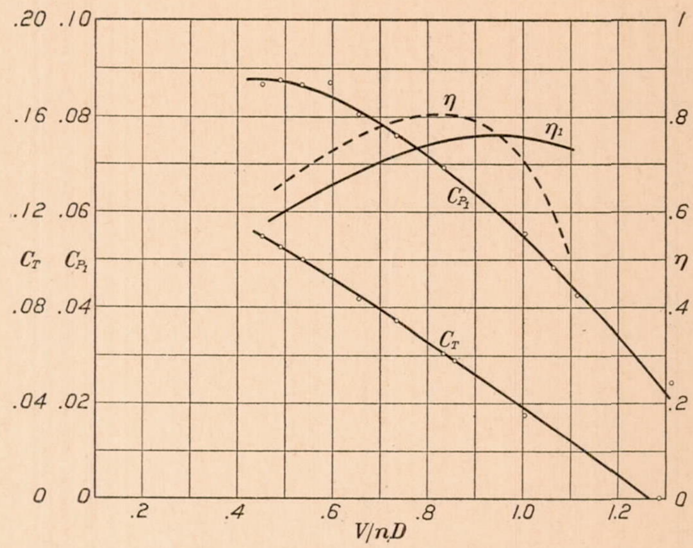

FIG. 35.—Propeller No. 2. Pitch ratio .9. Model C—DeHavilland. Clearance 0.375 inches. Radiator, closed

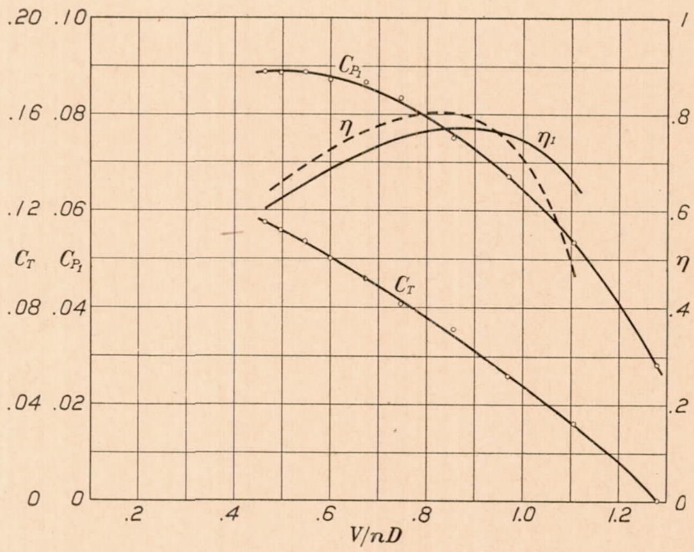

FIG. 36.—Propeller No. 2. Pitch ratio .9. Model C—DeHavilland. Clearance 4 inches. Radiator, closed

Other notation as per standard.

Graphical representations of these results are shown in the diagrams of Figures 10 to 36.

In these diagrams the individual values of the two coefficients are represented by the plotted points. A smooth curve as best indicating a continuous and consistent law is then drawn through and among these spots, and such curve is accepted as the best indication of the law relating the values of the coefficient to varying V/nD. The values of the efficiency η are then derived from the smooth curves of these coefficients and are plotted as shown in the various diagrams.

Tables I and II and Figures 10 and 11 give the results for the two propellers alone, and Tables III to XXVI and Figures 13 to 36 give those for the various combinations of propeller and model as stated. In each of the latter cases the efficiency curve for the propeller alone is also shown for comparison.

In Figure 12 are shown, for a single case, the curves for thrust and power coefficients with the resulting efficiency curves for the propeller alone and for the propeller with model. To avoid complication of diagrams, the coefficient curves for the propeller alone are omitted in Figures 13 to 36.

DISCUSSION OF RESULTS

In all cases, as shown on the various diagrams, the presence of an obstruction behind the propeller has the effect of moving to the right, on the axis of V/nD, the point for zero thrust. This is especially brought out in the diagram of Figure 12 where the coefficient curves for the propeller alone and for the propeller combined with model are shown together. Comparison with the other diagrams will show, in varying degrees, the same general condition.

This result is readily seen to follow as a natural consequence of the slowing down of the column of air actually operative on the propeller, as compared with the air passing freely at the side of the obstruction. For any given value of wind velocity as based on the latter, the air column acting on the propeller will be slowed down, the value of n for zero thrust will be decreased and the value of V/nD for zero thrust will be correspondingly increased.

From this shift of the point for zero thrust, it naturally results that the curve for thrust, or thrust coefficient, for the combined case, as compared with that for the propeller alone, starts farther to the right and near the start lies above that for the propeller alone. Hence for large values of V/nD (small values of the slip) the curve for propeller with model will lie above that for the propeller alone, as shown in Figures 12.

As the slip increases, however, and the value of V/nD becomes less, the two curves approach and meet and cross, thus bringing the values of the combination thrust coefficient for moderate and large values of the slip below those for the propeller alone. This condition, in general, is found to prevail over the normal working range of values of V/nD.

Similarly, for the torque coefficient, the values for large V/nD are greater than for the propeller alone, but the excess decreases with decreasing values of V/nD until the two sets of values become practically the same, and in many cases the curves cross and the values for the combination become less than those for the propeller alone.

It results that over the low value range of V/nD the values of the thrust coefficient for the combination are definitely less than for the propeller alone, while those for the power coefficient are nearly the same or slightly less. In all cases, however, and as illustrated in Figure 12, the decrease in the values of the thrust coefficient is greater than that for the power coefficient, and hence there results a loss in efficiency, as is shown in all cases.

On the other hand, however, and as must result from the forms of the coefficient curves, the values of the efficiency for large values of V/nD will be greater for the combination than for the propeller alone. Thus at the value of V/nD for zero thrust for the propeller alone, and hence for zero efficiency, the propeller combined with model will show a definite thrust and hence a definite (though low) efficiency. It thus results that the two efficiency curves must meet and cross, the combination values for moderate and low values of V/nD showing a loss as compared with the propeller alone, while over a range of relatively high V/nD (low slip) the combination values will be the larger.

It is well known that, due to limitations in diameter, air propellers must, in general, be used over a range of values of V/nD beginning with a large value somewhat less than that for maximum efficiency and extending over a small range in the direction of decreasing values. Inspection of Figures 13 to 36 will show that this range of values of V/nD carries the practical operation of the propeller over into that segment of the efficiency curve where the effect of an obstruction as represented by a thick wing, the nose of the fuselage, or other part of the airplane structure will be to decrease the propulsive efficiency as compared with that for the propeller alone at the same value of V/nD.

The amount of such loss in propulsive efficiency is seen to vary between wide limits according to the circumstances of the case. For model B, losses of the order of 15 and 20 points were found. For model A the values ranged somewhat smaller and for model C, as would be expected, still less.

A marked decrease in the loss is found to result from increased clearance between propeller and obstruction. This indicates very clearly that, in large degree, such loss in propulsive efficiency may be avoided by a suitable increase in this clearance, and, in general, it shows that with the tractor propeller the clearance between the propeller blades and the nearest parts of the airplane structure should be made as large as practicable.

So far as a comparison between the results for propellers 1 and 2 may serve to indicate, the loss in propulsive efficiency, other things the same, is the larger for No. 2 (the higher pitch ratio) than for No. 1.

The results of these observations indicate:

(1) The importance of taking some account, in problems of design, of this element of interaction between the propeller and the airplane.

(2) The desirability of avoiding such form and disposition of structure as will involve any extreme degree of interference as is shown by models A and B, or if such designs are imposed, then especial effort should be made to increase, to the maximum practicable limit, the clearance between the propeller and the nearer parts of the structure.

TABLE I

CHARACTERISTIC COEFFICIENTS FOR PROPELLER NO. 1

DIAMETER, 24 INCHES. NOMINAL PITCH RATIO, 0.70

$\frac{1}{2}\rho V^2$	V	N	T	Q	V/nD	C_T	C_{P_1}
1. 744	38. 70	1, 274	0. 180	0. 175	0. 9113	0. 0107	0. 0327
2. 363	45. 00	1, 716	1. 222	. 432	. 7868	. 0400	. 0445
2. 338	45. 34	1, 755	1. 237	. 446	. 7750	. 0397	. 0450
2. 059	42. 88	1, 905	2. 203	. 608	. 6752	. 0610	. 0529
2. 558	47. 56	2. 278	3. 601	. 969	. 6264	. 0691	. 0564
2. 360	45. 02	2, 169	3. 347	. 866	. 6227	. 0688	. 0559
2. 349	45. 47	2. 205	3. 370	. 879	. 6187	. 0687	. 0561
1. 837	39. 97	2, 090	3. 393	. 874	. 5737	. 0760	. 0590
2. 383	45. 29	2, 379	4. 437	1. 104	. 5711	. 0759	. 0593
2. 424	45. 72	2, 561	5. 550	1. 318	. 5356	. 0821	. 0613
2. 495	46. 39	2, 737	6. 724	1. 517	. 5085	. 0871	. 0617
2. 257	44. 50	2, 719	6. 715	1. 504	. 4910	. 0897	. 0631
2. 505	46. 50	3, 027	8. 874	1, 917	. 4608	. 0940	. 0638
2. 817	49. 35	3, 320	11. 050	2. 302	. 4459	. 0975	. 0638
2. 174	43. 30	3, 238	11. 150	2. 230	. 4011	. 1032	. 0648

TABLE II

CHARACTERISTIC COEFFICIENTS FOR PROPELLER NO. 2

DIAMETER, 24 INCHES. NOMINAL PITCH RATIO, 0.90

$\frac{1}{2}\rho V^2$	V	N	T	Q	V/nD	C_T	C_{P_1}
3. 860	58. 20	1, 501	0. 0882	0. 187	1. 163	0. 0039	0. 0257
1. 912	40. 95	1, 068	. 0617	. 145	1. 150	. 0053	. 0393
3. 879	58. 32	1, 762	1. 191	. 529	. 993	. 0378	. 0527
1. 946	41. 31	1, 384	1. 065	. 395	. 895	. 0548	. 0638
3. 870	58. 30	1, 994	2. 349	. 829	. 873	. 0603	. 0668
3. 879	58. 34	2, 166	3. 462	1. 121	. 808	. 0728	. 0741
1. 962	41. 53	1, 630	2. 213	. 657	. 764	. 0786	. 0768
2. 570	47. 28	1, 939	3. 312	. 971	. 731	. 0861	. 0793
2. 008	41. 85	1, 864	3. 305	. 934	. 674	. 0935	. 0830
2. 606	47. 65	2, 153	4. 508	1. 267	. 664	. 0953	. 0842
4. 050	59. 62	2, 929	8. 976	2. 349	. 611	. 1034	. 0851
2. 613	47. 77	2, 326	5. 562	1. 510	. 616	. 1010	. 0861
2. 016	42. 14	2, 226	5. 414	1. 422	. 568	. 1083	. 0893
4. 077	59. 82	3, 178	11. 334	2. 871	. 565	. 1109	. 0883
2. 716	48. 76	2, 787	8. 969	2. 231	. 525	. 1138	. 0889
2. 763	49. 17	3, 010	11. 092	2. 622	. 490	. 1205	. 0895
2. 273	44. 23	2, 920	11. 050	2. 519	. 454	. 1252	. 0897

TABLE III

PROPELLER NO. 1. PITCH RATIO, 0.7

MODEL A—WING

CLEARANCE, ⅜ INCH

$\frac{1}{2}\rho V^2$	V	N	T	R_a	R_o	A	$T-A$	Q	V/nD	C_T	C_{P_1}
1.885	40.80	1,279	0.648	0.877	0.603	0.274	0.374		0.9570	0.0227	
2.391	46.10	1,516	1.131	1.213	.765	.448	.683	0.332	.9123	.0297	0.0554
2.988	50.29	1,723	1.676	1.570	.956	.614	1.062	.448	.8756	.0341	.0451
3.122	51.51	1,944	2.602	1.930	.999	.931	1.671	.644	.7949	.0423	.0512
3.040	50.73	1,949	2.690	1.850	.973	.877	1.813	.665	.7810	.0455	.0524
2.401	46.21	1,804	2.338	1.562	.768	.794	1.544	.559	.7684	.0475	.0540
3.005	49.51	2,109	4.201	2.240	.963	1.277	2.924	.961	.6797	.0562	.0580
2.415	46.38	2,242	4.629	2.120	.773	1.347	3.282	.948	.6207	.0655	.0594
3.194	52.05	2,625	6.704	2.920	1.022	1.898	4.806	1.389	.5949	.0666	.0604
3.490	54.83	2,966	8.877	3.609	1.117	2.492	6.385	1.763	.5546	.0703	.0610
3.536	55.19	3,238	10.800	4.209	1.132	3.077	7.723	2.110	.5114	.0714	.0613
2.499	47.13	2,897	8.848	3.158	.800	2.358	6.490	1.617	.4880	.0773	.0605
2.255	45.70	3,004	10.043	3.362	.772	2.640	7.403	1.761	.4462	.0817	.0610
2.036	42.53	3,528	14.544	4.508	.652	3.856	10.688	2.366	.3616	.0858	.0596

TABLE IV

CLEARANCE, 2 INCHES

2.999	50.34	1,599	1.180	1.410	0.960	0.450	0.730	0.334	0.9442	0.0271	0.0390
2.902	49.58	1,622	1.213	1.325	.929	.396	.817	.352	.9172	.0296	.0401
3.126	51.13	1,900	2.370	1.690	1.000	.690	1.680	.597	.8074	.0438	.0489
4.152	60.50	2,478	4.666	2.507	1.329	1.178	3.488	1.091	.7325	.0563	.0554
3.683	56.75	2,565	5.645	2.539	1.179	1.360	4.285	1.239	.6643	.0642	.0583
3.306	52.89	2,491	5.579	2.420	1.058	1.362	4.217	1.208	.6370	.0647	.0582
3.753	57.22	2,869	7.751	3.017	1.201	1.815	5.936	1.607	.5978	.0707	.0601
2.491	46.73	2,601	6.742	2.322	.797	1.525	5.217	1.337	.5390	.0761	.0612
2.844	49.39	3,018	10.043	3.213	.910	2.303	7.740	1.837	.4909	.0820	.0611
3.238	52.38	3,378	13.430	4.140	1.036	3.104	10.326	2.340	.4652	.0863	.0614
2.530	47.11	3,140	11.160	3.248	.810	2.438	8.722	1.938	.4501	.0873	.0609
1.968	41.50	2,821	8.966	2.620	.630	1.990	6.976	1.541	.4413	.0863	.0599
1.964	41.47	3,079	11.100	3.013	.628	2.385	8.715	1.813	.4041	.0906	.0592
1.972	41.54	3,406						2.192	.3659		.0584

TABLE V

CLEARANCE, 4 INCHES

3.087	51.15	1,699	1.210	1.230	0.988	0.242	0.968	0.405	0.9032	0.0336	0.0420
4.508	63.05	2,158	2.192	1.870	1.442	.428	1.764	.649	.8764	.0376	.0434
3.554	55.84	2,024	2.218	1.592	1.137	.455	1.763	.631	.8277	.0425	.0478
3.100	51.28	1,950	2.360	1.450	.992	.458	1.902		.7890	.0478	
2.838	48.65	1,853						.573	.7878		.0492
4.662	64.20	2,585	4.428	2.374	1.491	.883	3.545	1.122	.7452	.0528	.0525
4.314	61.57	2,544	4.598	2.295	1.380	.915	3.683	1.108	.7260	.0563	.0532
1.902	41.28	1,744	2.192	1.051	.609	.442	1.750	.529	.7100	.0581	.0553
3.349	53.28	2,370	4.565	1.980	1.071	.909	3.656	1.053	.6745	.0621	.0562
3.080	52.03	2,333						.984	.6690		.0561
4.688	64.36	2,888						1.496	.6684		.0560
2.932	49.51	2,253	4.366	1.831	.939	.892	3.474		.6592	.0642	
4.288	61.43	2,851	6.812	2.632	1.371	1.261	5.551	1.486	.6465	.0676	.0569
4.716	64.57	3,174	8.876	3.162	1.509	1.653	7.223	1.884	.6102	.0713	.0584
1.936	41.65	2,142	4.157	1.411	.620	.786	3.371	.857	.5833	.0763	.0592
3.143	51.68	2,674	6.770	2.270	1.006	1.264	5.506	1.407	.5797	.0736	.0591
3.960	59.03	3,088	8.823	2.923	1.267	1.656	7.167	1.833	.5735	.0744	.0598
3.298	52.88	2,989	8.980	2.780	1.055	1.725	7.255	1.817	.5307	.0774	.0609
1.993	42.25	2,562	6.726	1.852	.638	1.214	5.512	1.264	.4948	.0846	.0610
2.578	47.38	3,160	11.090	2.757	.825	1.932	9.158	2.004	.4498	.0898	.0618
2.003	42.31	2,870	8.958	2.260	.641	1.619	7.339	1.594	.4423	.0896	.0608
1.986	42.13	3,144	10.990	3.197	.657	1.983	9.007	1.884	.4060	.0934	.0614
2.053	42.83	3,490	14.680	2.621	.638	2.540	12.140	2.335	.3681	.0987	.0605

V=Velocity f. p. s.
N=R. P. M.
n=r. p. s.
T=Actual thrust lb.
R_a=Resistance of model with propeller in action, lb.
R_o=Resistance of model without propeller at same speed as for R_a, lb.

A=Augment of resistance$=R_a-R_o$.
Q=Torque, ft. lb.
D=Diameter of propeller, ft.
C_T=Thrust coef.$=(T-A)\div\rho n^2D^4$
C_{P_1}=Power coef.$=P\div\rho n^3D^5$
P=Power$=2\pi nQ$ ft. lb. sec.

TABLE VI

PROPELLER NO. 2. PITCH RATIO, 0.9

MODEL A—WING

CLEARANCE, ⅜ INCH

$\frac{1}{2}\rho V^2$	V	N	T	R_a	R_o	A	$T-A$	Q	V/nD	C_T	C_{P_1}
1.904	40.65	1,098	0.701	0.886	0.609	0.277	0.424	0.257	1.110	0.0343	0.0653
4.933	65.59	1,850	2.263	2.573	1.579	.994	1.269		1.064	.0364	
2.349	45.55	1,297						.357	1.054		.0663
2.855	48.45	1,447	1.610	1.500	.914	.586	1.024		1.004	.0452	
3.578	56.08	1,720	2.243	1.886	1.145	.741	1.502	.683	.978	.0502	.0717
5.085	66.64	2,213	4.382	3.153	1.627	1.526	2.856		.903	.0572	
2.622	47.16	1,634	2.429	1.514	.839	.675	1.754	.687	.866	.0627	.0772
4,483	62.20	2,331	5.615	3.182	1.435	1.747	3.868	1.438	.802	.0694	.0810
5.117	67.00	2,800	8.910	4.403	1.637	2.766	6.144		.718	.0774	
1.885	40.66	1,750	3.416	1.535	.603	.932	2.484	.821	.697	.0800	.0831
3.896	57.95	2,686	8.852	3.700	1.247	2.453	6.399	1.951	.647	.0860	.0823
2.472	45.60	2,178	5.760	2.318	.786	1.532	4.228	1.316	.628	.0849	.0830
3.878	57.82	2,929	11.040	4.233	1.241	2.992	8.048	2.317	.592	.0909	.0823
1.928	41.21	2,122	5.599	2.060	.617	1.443	4.156		.582	.0912	
1.975	41.71	2,275	6.672	2.306	.632	1.674	4.998	1.361	.550	.0957	.0819
3.136	51.44	2,921	11.444	3.980	1.003	2.977	8.467	2.343	.528	.0944	.0818
1.985	41.82	2,806	11.032	3.269	.635	2.634	8.398	2.019	.447	.1057	.0798
1.995	41.93	3,166	14.404	3.942	.638	3.304	11.100	2.556	.397	.1096	.0793

TABLE VII

CLEARANCE 2 INCHES

4.222	60.73	1,793	2.293	2.020	1.351	0.669	1.624	0.712	1.0163	0.0496	0.0683
3.051	51.51	1,659	2.183	1.573	.976	.597	1.586	.657	.9324	.0563	.0733
4.234	60.84	2,187	4.472	2.583	1.354	1.229	3.243	1.221	.8345	.0667	.0789
1.929	40.67	1,537						.620	.7938		.0799
3.018	50.26	1,931	3.969	1.950	.966	.984	2.985		.7810	.0754	
4.305	61.37	2,498	6.660	2.997	1.377	1.620	5.040	1.654	.7370	.0795	.0820
3.005	50.15	2,237	5.954	2.360	.961	1.399	4.555	1.425	.6726	.0857	.0842
4.343	61.67	2,757	8.940	3.480	1.390	2.090	6.850	2.057	.6710	.0887	.0837
4.370	61.86	3,006	11.040	3.983	1.398	2.585	8.455	2.451	.6174	.0922	.0840
3.139	52.33	2,683	8.970	3.017	1.004	2.013	6.957	1.951	.5851	.0948	.0835
3.152	51.31	2,675	9.416	3.210	1.009	2.201	7.215	2.040	.5755	.0948	.0842
1.983	41.32	2,260	6.672	2.118	.634	1.484	5.188	1.393	.5485	.0984	.0830
3.173	52.61	2,907	11.100	3.502	1.015	2.487	8.613	2.276	.5430	.1000	.0830
3.173	51.49	2,946	11.690	3.680	1.015	2.665	9.025	2.474	.5243	.0977	.0842
2.043	41.93	2,560	8.866	2.626	.654	1.972	6.894	1.773	.4914	.1017	.0822
2.064	42.15	2,791	11.070	3.019	.660	2.359	8.711	2.061	.4531	.1084	.0805
2.091	42.48	3,144	14.390	3.743	.669	3.074	11.316	2.591	.4053	.1112	.0799

TABLE VIII

CLEARANCE, 4 INCHES

1.857	40.61	1,277	1.178	0.808	0.594	0.214	0.964	0.354	0.9540	0.0591	0.0681
3.200	53.03	1,724	2.304	1.530	1.024	.506	1.798	.683	.9228	.0599	.0714
4.947	66.36	2,313	4.530	2.534	1.583	.951	3.579	1.275	.8608	.0670	.0750
3.177	51.80	1,995	3.969	1.770	1.017	.753	3.216	1.056	.7790	.0768	.0792
4.932	66.29	2,608	6.660	2.869	1.578	1.291	5.369	1.731	.7625	.0793	.0801
3.228	53.33	2,120	4.448	1.888	1.038	.850	3.598	1.159	.7547	.0793	.0803
3.143	51.32	2,086	4.609	1.870	1.007	.863	3.746	1.186	.7380	.0811	.0807
3.207	52.59	2,368	6.318	1.748	.642	1.106	5.212	1.519	.6667	.0858	.0827
3.137	51.62	2,418	7.123	2.320	1.015	1.305	5.818	1.678	.6404	.0940	.0852
3.825	58.23	2,996	10.910	3.263	1.224	2.039	8.871	2.427	.5831	.0986	.0847
3.332	52.95	2,986	11.732	3.170	1.066	2.104	9.628	2.546	.5320	.1022	.0849
2.270	44.57	2,615	8.876	2.356	.726	1.630	7.246	1.851	.5113	.1043	.0837
2.272	44.62	2,867	11.065	2.726	.727	1.999	9.066	2.188	.4669	.1087	.0824
2.007	42.41	3,042	12.745	2.923	.642	2.281	10.464	2.420	.4182	.1130	.0824

V=Velocity f. p. s.
N=R. P. M.
n=r. p. s.
T=Actual thrust, lb.
R_a=Resistance of model with propeller in action, lb.
R_o=Resistance of model without propeller at same speed as for R_a, lb.

A=Augment of resistance=R_a-R_o.
Q=Torque, ft. lb.
D=Diameter of propeller, ft.
C_T=Thrust Coef.=$(T-A)\div\rho n^2D^4$.
C_{P_1}=Power Coef.=$P\div\rho n^3D^5$.
P=Power=$2\pi nQ$ ft. lb. sec

TABLE IX

PROPELLER No. 1. PITCH RATIO, 0.7

MODEL B—FUSELAGE

CLEARANCE, 3/8 INCH

$\frac{1}{2}\rho V^2$	V	N	T	R_a	R_o	A	$T-A$	Q	V/nD	C_T	C_{P_1}
4.730	64.60	1,951	1.298	5.076	4.170	0.906	0.392	0.441	0.9932	0.0102	0.0361
3.068	51.70	1,604	1.028	3.286	2.651	.635	.393	.338	.9678	.0150	.0405
1.905	41.20	1,299	.666	1.991	1.675	.316	.350	.224	.9515	.0208	.0418
3.060	51.65	1,882	2.238	3.635	2.648	.987	1.251	.589	.8234	.0347	.0513
1.875	40.85	1,738	2.338	2.469	1.642	.827	1.511	.576	.7052	.0501	.0600
4.235	61.30	2,780	6.620	6.065	3.740	2.325	4.295	----------	.6616	.0555	----------
4.235	61.45	3,085	8.820	6.760	3.755	3.005	5.815	1.987	.5975	.0613	.0658
3.170	52.70	2,650	6.640	5.013	2.756	2.257	4.383	1.500	.5966	.0615	.0662
1.913	41.40	2,193	4.560	3.158	1.695	1.463	3.097	1.015	.5663	.0649	.0670
4.225	61.35	3,330	11.140	7.251	3.748	3.503	7.637	2.356	.5528	.0691	.0669
3.175	52.70	2,964	8.980	5.617	2.756	2.866	6.119	1.921	.5334	.0686	.0676
3.196	52.95	3,213	11.080	6.236	2.785	3.451	7.629	2.285	.4944	.0729	.0686
1.997	42.27	2,855	8.950	4.505	1.772	2.733	6.217	1.726	.4441	.0768	.0670
2.010	42.43	3,122	11.140	5.135	1.790	3.345	7.795	2.067	.4077	.0806	.0676
2.040	42.77	3,460	14.310	6.026	1.820	4.206	10.104	2.511	.3709	.0852	.0665

TABLE X

CLEARANCE, 2 INCHES

4.348	61.25	1,889	1.172	4.305	3.632	0.673	0.499	0.418	0.9728	0.0136	0.0357
3.357	52.71	1,793	1.638	3.762	2.750	.626	1.012	.478	.8845	.0295	.0438
2.815	49.18	1,875	2.290	3.154	2.409	.745	1.545	.587	.7868	.0425	.0507
4.650	63.40	2,510	4.565	5.490	4.010	1.480	3.085	1.120	.7578	.0476	.0543
4.640	63.35	2,834	6.650	6.006	4.001	2.005	4.645	1.585	.6706	.0563	.0604
2.240	43.55	1,988	3.510	3.878	1.885	1.993	1.517	.808	.6572	.0607	.0612
2.937	50.25	2,595	6.690	4.300	2.512	1.783	4.902	1.435	.3809	.0704	.0657
3.073	49.63	2,621	7.362	4.656	2.610	2.044	5.318	----------	.5681	.0698	----------
1.582	36.80	2,258	5.635	2.794	1.290	1.504	4.131	1.124	.4890	.0781	.0667
2.960	50.30	3,178	11.210	5.456	2.535	2.921	8.289	2.194	.4768	.0796	.0662
1.629	37.34	2,725	8.945	3.682	1.335	2.347	6.598	1.645	.4111	.0856	.0671
1.637	37.44	3,002	11.190	4.285	1.344	2.941	8.249	2.017	.3742	.0882	.0678
1.645	37.33	3,351	14.380	5.130	1.352	3.778	10.602	2.462	.3361	.0912	.0664

TABLE XI

CLEARANCE, 4 INCHES

4.360	61.35	1,918	1.142	4.161	3.747	0.414	0.728	0.464	0.9598	0.0195	0.0385
1.802	39.52	1,345	----------	----------	----------	----------	----------	.257	.8816	----------	.0435
3.295	53.25	1,982	2.365	3.496	2.810	.686	1.679	.633	.8060	.0414	.0491
4.390	61.65	2,514	4.475	5.031	3.783	1.248	3.227	1.120	.7358	.0498	.0543
3.286	53.15	2,359	4.575	3.994	2.805	1.189	3.386	1.058	.6760	.0589	.0577
3.699	55.55	2,553	5.459	4.163	3.040	1.123	4.336	1.315	.6528	.0625	.0595
3.186	51.31	2,616	6.175	4.036	2.615	1.421	4.754	1.436	.6002	.0672	.0638
2.600	46.88	2,576	6.660	3.710	2.175	1.535	5.125	1.455	.5464	.0736	.0656
2.638	47.33	2,882	8.910	4.197	2.205	1.992	6.918	1.849	.4927	.0796	.0669
1.932	41.04	2,833	8.855	3.501	1.662	1.839	7.016	1.740	.4346	.0858	.0668
1.983	41.60	3,132	11.170	4.098	1.712	2.386	8.784	2.132	.3985	.0879	.0671

V=Velocity f. p. s.
N=R. P. M.
n=r. p. s.
T=Actual thrust, lb.
R_a=Resistance of model with propeller in action, lb.
R_o=Resistance of model without propeller at same speed as for R_a, lb.

A=Augment of resistance=R_a-R_o.
Q=Torque, ft. lb.
D=Diameter of propeller, ft.
C_T=Thrust coef.=$(T-A)\div\rho n^2 D^4$.
C_{P_1}=Power coef.=$P\div\rho n^3 D^5$.
P=Power=$2\pi n Q$ ft. lb. sec.

TABLE XII

PROPELLER NO. 2. PITCH RATIO, 0.9

MODEL B—FUSELAGE

CLEARANCE, ⅜ INCH

$\frac{1}{2}\rho V^2$	V	N	T	R_a	R_o	A	$T-A$	Q	V/nD	C_T	C_{P_1}
4. 401	62. 15	1, 613	1. 261	4. 711	3. 867	0. 844	0. 417	0. 427	1. 1560	0. 0158	0. 0509
4. 293	61. 45	1, 826	2. 378	4. 932	3. 755	1. 177	1. 201	. 704	1. 0098	. 0356	. 0656
1. 643	38. 36	1, 244	1. 232	1. 907	1. 425	. 482	. 750	. 360	. 9250	. 0488	. 0737
4. 315	61. 70	2, 177	4. 525	5. 440	3. 629	1. 811	2. 714	1. 221	. 8503	. 0568	. 0804
4. 448	62. 70	2, 519	6. 875	6. 378	3. 919	2. 459	4. 416	----------	. 7468	. 0692	----------
2. 821	48. 56	1, 963	4. 212	3. 827	2. 357	1. 470	2. 742	1. 139	. 7421	. 0669	. 0873
4. 443	62. 70	2, 745	8. 790	6. 864	3. 919	2. 945	5. 845	2. 202	. 6853	. 0772	. 0914
2. 792	50. 11	2, 371	6. 715	4. 554	2. 494	2. 060	4. 655	1. 597	. 6341	. 0838	. 0903
4. 428	62. 70	3, 022	11. 230	7. 509	3. 919	3. 590	7. 640	----------	. 6225	. 0832	----------
2. 950	51. 53	2, 667	8. 875	5. 308	2. 645	2. 663	6. 212	----------	. 5800	. 0886	----------
3. 015	50. 25	2, 643	9. 482	5. 350	2. 535	2. 815	6. 667	2. 141	. 5704	. 0899	. 0908
2. 405	46. 07	2, 591	8. 922	4. 663	2. 021	2. 642	6. 280	1. 967	. 5340	. 0931	. 0916
1. 923	41. 31	2, 550	8. 905	4. 281	1. 687	2. 594	6. 311	1. 843	. 4860	. 0969	. 0889
1. 939	41. 52	2, 794	11. 075	4. 882	1. 706	3. 176	7. 899	2. 208	. 4459	. 1013	. 0889
1. 975	41. 90	3, 154	14. 410	5. 876	1. 740	4. 136	10. 274	2. 788	. 3986	. 1013	. 0881

TABLE XIII

CLEARANCE, 2 INCHES

3. 031	50. 64	1, 353	0. 910	2. 929	2. 549	0. 380	0. 530	0. 334	1. 1175	0. 0273	0. 0540
2. 795	49. 10	1, 384	1. 160	1. 766	1. 350	. 416	. 744	. 373	1. 0644	. 0377	. 0594
4. 163	60. 10	1, 808	2. 300	4. 494	3. 590	. 904	1. 396	. 727	. 9973	. 0417	. 0682
1. 893	41. 10	1, 285	1. 210	2. 073	1. 668	. 405	. 805	. 378	. 9597	. 0490	. 0722
2. 720	48. 45	1, 631	2. 310	3. 054	2. 340	. 714	1. 596	. 655	. 8912	. 0582	. 0751
4. 200	60. 45	2, 170	4. 510	5. 203	3. 630	1. 573	2. 937	1. 253	. 8358	. 0611	. 0819
1. 913	41. 35	1, 561	2. 325	2. 326	1. 690	. 636	1. 679	. 650	. 7947	. 0693	. 0843
3. 492	54. 72	2, 259	5. 640	4. 552	2. 936	1. 616	4. 024	1. 491	. 7268	. 0761	. 0886
1. 925	41. 50	1, 776	3. 420	2. 559	1. 708	. 851	2. 569	. 880	. 7010	. 0820	. 0883
3. 082	51. 17	2, 361	6. 685	4. 439	2. 590	1. 849	4. 836	1. 711	. 6502	. 0829	. 0922
2. 800	49. 17	2, 332	6. 670	4. 135	2. 407	1. 728	4. 942	1. 663	. 6326	. 0883	. 0934
3. 082	51. 17	2, 551	8. 287	4. 815	2. 591	2. 224	6. 063	2. 017	. 6018	. 0891	. 0931
2. 830	49. 46	2, 613	8. 935	4. 730	2. 432	2. 298	6. 637	2. 107	. 5679	. 0945	. 0943
2. 845	49. 60	2, 850	11. 100	5. 296	2. 450	2. 846	8. 254	2. 480	. 5221	. 0992	. 0937
2. 005	42. 40	2, 580	8. 835	3. 938	1. 786	2. 152	6. 683	1. 983	. 4930	. 1013	. 0944
2. 035	42. 75	2, 841	11. 040	4. 652	1. 819	2. 833	8. 207	2. 378	. 4514	. 1028	. 0936
2. 025	42. 65	3, 158	14. 090	5. 419	1. 807	3. 612	10. 478	2. 902	. 4052	. 1062	. 0925

TABLE XIV

CLEARANCE, 4 INCHES

4. 080	59. 10	1, 601	1. 129	3. 893	3. 447	0. 446	0. 683	----------	1. 1080	0. 0257	----------
2. 983	50. 35	1, 428	----------	----------	----------	----------	----------	0. 380	1. 0580	----------	0. 0556
1. 422	35. 15	1, 071	. 746	1. 431	1. 148	. 283	. 463	. 244	. 9846	. 0395	. 0653
2. 232	43. 03	1, 450	1. 746	2. 408	1. 877	. 531	1. 215	. 336	. 8904	. 0539	. 0748
4. 067	59. 15	2, 189	4. 470	4. 705	3. 452	1. 253	3. 217	1. 262	. 8108	. 0650	. 0801
3. 003	50. 60	2, 067	4. 600	3. 689	2. 547	1. 142	3. 458	1. 205	. 7344	. 0776	. 0850
4. 164	59. 85	2, 496	6. 725	5. 219	3. 560	1. 659	5. 066	1. 763	. 7192	. 0787	. 0860
3. 095	51. 33	2, 368	6. 650	4. 192	2. 616	1. 576	5. 074	1. 678	. 6504	. 0867	. 0901
4. 192	60. 05	2, 772	8. 910	5. 761	3. 585	2. 176	6. 734	2. 274	. 6499	. 0848	. 0900
4. 233	60. 35	3, 010	11. 090	6. 272	3. 615	2. 657	8. 433	2. 705	. 6015	. 0901	. 0908
3. 095	51. 35	2, 645	8 875	4. 668	2. 618	2. 050	6. 825	2. 153	. 5825	. 0935	. 0927
1. 816	39. 83	2, 273	6. 700	3. 082	1. 555	.. 527	5. 173	1. 551	. 5257	. 0984	. 0927
2. 107	42. 98	2, 585	8. 935	3. 730	1. 839	1. 891	7. 044	2. 052	. 4988	. 1040	. 0952
1. 530	36. 10	2, 767	11. 270	3. 792	1. 230	2. 562	8. 708	2. 373	. 3914	. 1090	. 0933

V=Velocity f. p. s
N=R. P. M.
n=R. p. s.
T=Actual thrust, lb.
R_a=Resistance of model with propeller in action, lb.
R_o=Resistance of model without propeller at same speed as for R_a, lb.

A=Augment of resistance=R_a—R_o.
Q=Torque, ft. lb.
D=Diameter of propeller, ft.
C_T=Thrust coef.=$(T-A)\div\rho n^2D^4$.
C_{P_1}=Power coef.=$P\div\rho n^3D^5$.
P=Power=$2\pi\ nQ$ ft. lb. sec.

TABLE XV

PROPELLER NO. 1. PITCH RATIO, 0.7

MODEL C—DeHAVILLAND

CLEARANCE, ⅜ INCH

RADIATOR—WIRE GAUZE

$\frac{1}{2}\rho V^2$	V	N	T	R_a	R_o	A	T-A	Q	V/nD	C_T	C_{P_1}
3.110	50.90	1,430	0.000	0.890	0.788	----------	----------	0.175	1.065	----------	0.0252
3.100	50.84	1,616	.706	.965	.785	0.180	0.526	.319	.941	0.0189	.0360
3.148	51.26	1,729	1.434	1.045	.798	.247	1.187	.463	.855	.0344	.0422
3.138	51.20	2,050	2.646	1.170	.795	.375	2.271	.705	.749	.0509	.0496
3.185	51.60	2,340	4.080	1.340	.806	.534	3.546	1.038	.662	.0609	.0559
3.321	52.70	2,661	5.955	1.560	.841	.719	5.236	1.406	.594	.0696	.0587
3.300	52.55	2,944	8.180	1.785	.835	.950	7.230	1.797	.536	.0785	.0613
3.335	52.80	3,226	10.540	2.020	.844	1.176	9.364	2.228	.491	.0847	.0633
3.358	53.00	3,561	13.450	2.345	.850	1.495	11.955	2.787	.447	.0886	.0650
3.365	53.10	3,850	16.430	2.660	.852	1.808	14.622	3.221	.414	.0930	.0643
.110	9.60	3,051	13.340	1.545	.028	1.517	13.823	1.852	.094	.1196	.0588

TABLE XVI

CLEARANCE, 4 INCHES

3.009	50.50	1,474	----------	0.670	0.652	----------	----------	0.159	1.027	----------	0.0220
3.027	50.67	1,654	0.662	.715	.656	0.059	0.603	.325	.919	0.0210	.0356
3.027	50.67	1,851	1.477	.770	.656	.114	1.363	.509	.822	.0380	.0446
2.997	50.40	2,085	2.668	.850	.649	.201	2.467	.737	.725	.0542	.0508
3.128	51.52	2,380	4.145	.985	.678	.307	3.838	1.060	.649	.0647	.0561
3.168	51.85	2,682	5.930	1.440	.686	.454	5.476	1.448	.580	.0727	.0604
3.180	51.96	2,978	8.090	1.290	.689	.601	7.489	1.828	.523	.0807	.0619
3.208	52.20	3,263	10.580	1.450	.695	.755	9.825	2.257	.480	.0881	.0636
3.373	53.50	3,602	13.340	1.690	.731	.959	12.381	2.821	.446	.0911	.0652
3.467	54.25	3,899	16.540	1.925	.751	1.174	15.366	3.347	.418	.0971	.0660
.110	9.59	3,066	13.400	1.095	.024	1.071	12.329	1.917	.094	.1231	.0601

TABLE XVII

PROPELLER NO. 2. PITCH RATIO, 0.9

CLEARANCE, ⅜ INCH

3.102	50.98	1,178	----------	0.855	0.785	----------	----------	0.112	1.299	----------	0.0251
3.107	51.02	1,588	1.452	1.015	.787	0.228	1.224	.516	.964	.0459	.0606
3.074	50.75	1,387	.684	.930	.779	.151	.533	.297	1.097	.0261	.0458
3.107	51.02	1,819	2.624	1.120	.787	.333	2.291	.772	.843	.0653	.0692
3.138	51.30	2,101	4.124	1.290	.794	.496	3.628	1.172	.732	.0775	.0786
3.243	52.13	2,376	5.932	1.485	.821	.664	5.268	1.591	.658	.0880	.0835
3.274	52.38	2,662	8.160	1.715	.829	.886	7.274	2.040	.590	.0968	.0853
3.300	52.60	2,964	10.540	1.965	.835	1.130	9.410	2.551	.532	.1010	.0861
3.400	53.38	3,240	13.430	2.240	.861	1.379	12.051	3.055	.494	.1082	.0862
3.428	53.59	3,526	16.540	2.575	.868	1.707	14.833	3.655	.456	.1125	.0871
.114	9.79	2,905	13.300	1.580	.029	1.551	11.749	2.231	.101	.1311	.0782

TABLE XVIII

CLEARANCE, 4 INCHES

2.996	49.81	1,181	----------	0.645	0.649	----------	----------	0.137	1.264	----------	0.0288
3.000	49.83	1,388	0.684	.640	.650	0.010	0.674	.342	1.077	0.0330	.0519
2.990	49.80	1,574	1.499	.740	.648	.092	1.407	.559	.949	.0529	.0664
3.037	50.18	1,817	2.668	.845	.658	.187	2.481	.827	.828	.0700	.0733
3.075	50.50	2,093	4.124	.955	.666	.289	3.835	1.175	.724	.0817	.0786
3.177	51.34	2,353	5.954	1.100	.688	.418	5.536	1.581	.654	.0933	.0837
3.264	52.01	2,653	8.204	1.280	.707	.573	7.631	2.073	.588	.1011	.0862
3.350	52.80	2,956	10.580	1.485	.725	.760	9.820	2.586	.536	.1050	.0869
3.410	53.25	3,231	13.400	1.690	.739	.951	12.449	3.084	.495	.1115	.0868
3.500	53.94	3,528	16.540	1.915	.758	1.157	15.383	3.699	.459	.1137	.0874
.150	11.15	3,165	16.560	1.063	.032	1.031	15.529	2.840	.106	.1450	.0833

V=Velocity f. p. s.
N=R. P. M.
n=r. p. s.
T=Actual thrust, lb.
R_a=Resistance of model with propeller in action, lb.
R_o=Resistance of model without propeller at same speed as for R_a, lb.

A=Augment of resistance=R_a-R_o.
Q=Torque, ft. lb.
D=Diameter of propeller, ft.
C_T=Thrust coef.=$(T-A)\div\rho n^2D^4$.
C_{P_1}=Power coef.=$P\div\rho n^3D^5$.
P=Power=$2\pi nQ$ ft. lb. sec.

TABLE XIX

PROPELLER NO. 1. PITCH RATIO, 0.7

MODEL C—DeHAVILLAND

CLEARANCE, ⅜ INCH

RADIATOR—SPACE OPEN

$\frac{1}{2}\rho V^2$	V	N	T	R_a	R_o	A	$T-A$	Q	V/nD	C_T	C_{P_1}
2.820	49.16	1,395	0.001	0.745	0.664	----------	----------	0.103	1.059	----------	0.0160
2.864	49.60	1,610	.684	.840	.676	0.164	0.520	.277	.924	0.0194	.0324
2.909	50.00	1,827	1.521	.935	.685	.250	1.271	.451	.821	.0368	.0410
3.032	51.04	2,097	2.712	1.085	.714	.371	2.341	.710	.730	.0514	.0490
3.124	51.85	2,355	4.080	1.235	.736	.499	3.581	.969	.661	.0626	.0532
3.102	51.67	2,680	6.040	1.425	.731	.694	5.346	1.367	.579	.0721	.0579
3.110	51.75	2,971	8.016	1.625	.732	.893	7.123	1.772	.522	.0782	.0611
3.067	51.38	3,258	10.700	1.810	.722	1.088	9.612	2.134	.473	.0877	.0611
3.150	52.10	3,261	10.630	1.855	.743	1.112	9.518	2.156	.480	.0868	.0618
3.185	52.43	3,564	13.070	2.105	.750	1.355	11.715	2.629	.442	.0896	.0631
3.252	52.97	3,951	16.270	2.481	.767	1.714	14.556	3.130	.402	.0905	.0612
.106	9.40	3,068	13.350	1.398	.025	1.373	11.977	1.877	.092	.1198	.0591

TABLE XX

CLEARANCE, 4 INCHES

3.062	51.80	1,504	----------	0.744	0.707	----------	----------	0.134	1.033	----------	0.0183
3.078	51.91	1,700	0.661	.719	.641	0.078	0.583	.285	.916	.0199	.0305
3.119	52.26	1,906	1.522	.737	.607	.130	1.392	.488	.825	.0378	.0146
3.113	52.22	2,151	2.647	.819	.606	.213	2.434	.736	.728	.0518	.0492
3.183	52.80	2,398	4.051	.925	.620	.305	3.746	1.016	.661	.0643	.0547
3.240	53.28	2,745	6.076	1.069	.630	.439	5.536	1.448	.582	.0737	.0594
3.107	51.87	2,981	8.090	1.155	.604	.551	7.539	1.784	.522	.0827	.0614
3.115	51.95	3,297	10.670	1.335	.606	.729	9.941	2.232	.473	.0891	.0628
3.234	52.94	3,620	13.340	1.530	.629	.901	12.439	2.690	.438	.0925	.0628
3.256	53.11	3,908	16.580	1.710	.634	1.076	15.504	3.243	.408	.0990	.0650
.128	10.34	3,000	13.380	1.045	.025	1.020	12.360	1.933	.103	.1321	.0649

TABLE XXI

PROPELLER NO. 2. PITCH RATIO, 0.9

CLEARANCE, ⅜-INCH

3.190	53.06	1,237	----------	0.680	0.710	----------	----------	0.108	1.287	----------	0.0221
3.199	53.18	1,421	0.661	.858	.752	0.106	0.555	.282	1.123	0.0273	.0437
3.140	52.69	1,644	1.544	.964	.754	.212	1.332	.506	.962	.0490	.0585
3.177	52.99	1,888	2.648	1.045	.742	.303	2.345	.839	.842	.0654	.0735
3.021	51.63	2,118	4.169	1.095	.734	.361	3.808	1.169	.732	.0831	.0805
3.171	52.20	2,391	5.978	1.245	.748	.497	5.481	1.566	.655	.0927	.0831
3.278	53.05	2,692	8.072	1.470	.773	.697	7.375	2.007	.592	.0983	.0841
3.239	52.67	3,002	10.580	1.735	.762	.973	9.607	3.574	.526	.1030	.0867
3.250	52.90	3,260	13.420	1.985	.767	1.218	12.202	3.008	.487	.1112	.0861
3.391	54.05	3,550	16.510	2.295	.800	1.495	15.015	3.546	.457	.1155	.0857
3.299	53.31	2,983	10.580	1.745	.778	.967	9.613	2.497	.536	.1047	.0834

TABLE XXII

CLEARANCE, 4 INCHES

2.842	49.65	1,176	----------	0.545	0.553	----------	----------	0.054	1.267	----------	0.0120
2.948	50.58	1,411	0.661	.615	.573	0.042	0.619	.285	1.075	0.0304	.0439
2.960	50.73	1,610	1.477	.675	.576	.099	1.378	.508	.944	.0519	.0601
2.992	50.99	1,870	2.669	.775	.582	.193	2.476	.812	.818	.0693	.0713
2.965	50.77	2,113	4.169	.840	.577	.263	3.906	1.129	.721	.0852	.0776
3.070	51.65	2,396	5.978	.975	.590	.385	5.593	1.570	.647	.0952	.0839
3.110	52.02	2,683	8.025	1.125	.606	.519	7.506	2.047	.582	.1016	.0871
3.090	51.78	2,973	10.620	1.280	.601	.679	9.941	2.487	.521	.1097	.0862
3.467	54.85	3,300	13.450	1.510	.674	.836	12.614	3.097	.498	.1129	.0871
3.530	55.34	3,576	16.490	1.705	.686	1.019	15.471	3.658	.465	.1180	.0876

V = Velocity f. p. s.
N = R. P. M.
n = r. p. s.
T = Actual thrust, lb.
R_a = Resistance of model with propeller in action, lb.
R_o = Resistance of model without propeller at same speed as for R_a, lb.

A = Augment of resistance = $R_a - R_o$.
Q = Torque, ft. lb.
D = Diameter of propeller, ft.
C_T = Thrust coef. = $(T-A) \div \rho\, n^2 D^4$.
C_{P_1} = Power coef. = $P \div \rho\, n^3 D^5$.
P = Power = $2\pi nQ$ ft. lb. sec.

TABLE XXIII

PROPELLER NO. 1. PITCH RATIO, 0.7

MODEL C—DeHAVILLAND

CLEARANCE, ⅜ INCH

RADIATOR—CLOSED

$\frac{1}{2}\rho V^2$	V	N	T	R_a	R_o	A	$T-A$	Q	V/nD	C_T	C_{P_1}
3.089	51.20	1,448	----------	1.100	0.958	----------	----------	0.127	1.060	----------	0.0181
3.129	51.60	1,623	----------	1.055	.952	----------	----------	.292	.952	----------	.0333
3.071	51.15	1,624	0.684	1.170	.952	0.218	0.466	.286	.946	0.0169	.0326
3.071	51.15	1,802	1.433	1.275	.952	.323	1.110	.449	.851	.0328	.0416
3.137	51.75	2,073	2.646	1.465	.973	.492	2.154	.698	.748	.0481	.0490
3.185	52.20	2,348	4.057	1.655	.987	.668	3.389	.986	.667	.0591	.0540
3.300	53.10	2,674	6.019	1.945	1.023	.922	5.097	1.358	.597	.0685	.0573
3.260	52.90	2,956	8.138	2.150	1.010	1.140	6.998	1.723	.536	.0774	.0598
3.260	52.90	3,261	10.580	2.465	1.010	1.455	9.125	2.152	.487	.0829	.0614
3.343	53.60	3,580	13.410	2.835	1.035	1.800	11.610	2.578	.449	.0875	.0610
3.382	53.90	3,879	16.530	3.315	1.048	2.267	14.263	3.091	.418	.0916	.0624

TABLE XXIV

CLEARANCE, 4 INCHES

3.080	51.79	1,531	----------	0.830	0.900	----------	----------	0.192	1.015	----------	0.0237
3.084	51.84	1,484	----------	.835	.903	----------	----------	.145	1.049	----------	.0202
3.088	51.94	1,670	0.661	.895	.903	----------	0.661	.340	.933	0.0232	.0376
3.180	52.68	2,128	2.679	1.105	.928	0.177	2.502	.745	.743	.0542	.0507
3.303	53.68	2,692	5.955	1.485	.965	.520	5.435	1.427	.598	.0735	.0606
3.343	54.03	3,290	10.580	1.960	.976	.984	9.596	2.236	.492	.0869	.0636
3.409	54.54	3,909	16.620	2.625	.995	1.630	14.990	3.300	.418	.0962	.0666
3.422	54.65	3,593	13.330	2.275	.998	1.277	12.053	2.744	.455	.0913	.0655
3.343	54.02	2,969	8.025	1.690	.976	.714	7.311	1.824	.546	.0814	.0638
3.199	52.84	2,385	3.970	1.265	.934	.331	3.639	1.073	.664	.0628	.0582
3.199	52.84	1,888	1.477	1.000	.934	.066	1.411	.561	.839	.0389	.0486

TABLE XXV

PROPELLER NO. 2. PITCH RATIO, 0.9

CLEARANCE, ⅜ INCH

3.353	53.91	1,258	----------	1.040	1.040	----------	----------	0.1367	1.286	----------	0.0326
3.353	53.98	1,615	1.323	1.420	1.040	0.380	0.943	.4702	1.003	0.0354	.0554
3.353	54.03	1,893	2.646	1.575	1.040	.535	2.111	----------	.856	.0577	----------
3.110	52.44	1,889	2.648	1.439	.965	.474	2.174	.0818	.833	.0606	.0691
3.180	52.71	2,146	4.124	1.657	.990	.667	3.457	.1353	.734	.0744	.0758
3.190	53.10	2,430	5.856	1.870	.992	.878	4.978	.1518	.656	.0838	.0804
3.295	52.90	2,661	8.000	2.095	1.023	1.072	6.928	.2846	.596	.0933	.0871
3.318	53.10	2,970	10.780	2.440	1.029	1.411	9.369	.3514	.536	.1015	.0865
3.309	53.07	2,963	10.590	2.435	1.026	1.409	9.181	.3487	.537	.1000	.0863
3.327	53.20	3,253	13.410	2.785	1.032	1.753	11.657	.4264	.490	.1053	.0875
3.340	53.33	3,536	16.550	3.245	1.036	2.209	14.341	.4990	.452	.1094	.0867

TABLE XXVI

CLEARANCE 4 INCHES

3.137	52.36	1,226	----------	0.885	0.916	----------	----------	0.138	1.280	----------	0.0284
3.160	52.54	1,422	0.662	.920	.923	----------	0.662	.347	1.108	0.0322	.0531
3.177	52.73	1,631	1.477	1.005	.928	0.077	1.400	.576	.970	.0518	.0671
3.190	52.83	1,852	2.646	1.105	.932	.173	2.473	.833	.856	.0710	.0751
3.248	53.30	2,142	4.123	1.275	.948	.327	3.796	1.233	.746	.0815	.0832
3.353	54.17	2,418	5.953	1.485	.979	.506	5.447	1.639	.672	.0918	.0867
3.340	54.00	2,700	8.136	1.690	.975	.715	7.421	2.061	.600	.1001	.0873
3.374	54.30	2,977	10.590	1.940	.986	.954	9.636	2.545	.547	.1070	.0888
3.357	54.17	3,268	13.400	2.225	.981	1.244	12.156	3.067	.497	.1120	.0887
3.480	55.15	3,558	16.510	2.595	1.016	1.579	14.931	3.709	.463	.1152	.0899

V=Velocity f. p. s.
N=R. P. M.
n=r. p. s.
T=Actual thrust, lb.
R_a=Resistance of model with propeller in action, lb.
R_o=Resistance of model without propeller at same speed as for R_a, lb.

A=Augment of resistance=R_a—R_o.
Q=Torque, ft. lb.
D=Diameter of propeller, ft.
C_T=Thrust coef.=$(T-A)\div\rho n^2D^4$.
C_{P_1}=Power coef.=$P\div\rho n^3D^5$.
P=Power=$2\pi nQ$ ft., lb. sec.

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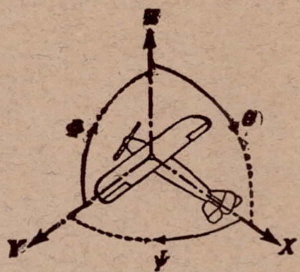

Positive directions of axes and angles (forces and moments) are shown by arrows

Axis		Force (parallel to axis) symbol	Moment about axis			Angle		Velocities	
Designation	Symbol		Designation	Symbol	Positive direction	Designation	Symbol	Linear (component along axis)	Angular
Longitudinal	X	X	rolling	L	$Y \longrightarrow Z$	roll	Φ	u	p
Lateral	Y	Y	pitching	M	$Z \longrightarrow X$	pitch	Θ	v	q
Normal	Z	Z	yawing	N	$X \longrightarrow Y$	yaw	Ψ	w	r

Absolute coefficients of moment

$$C_l=\frac{L}{qbS} \quad C_m=\frac{M}{qcS} \quad C_n=\frac{N}{qfS}$$

Angle of set of control surface (relative to neutral position), δ. (Indicate surface by proper subscript.)

4. PROPELLER SYMBOLS

Diameter, D

Pitch (a) Aerodynamic pitch, p_a

(b) Effective pitch, p_e

(c) Mean geometric pitch, p_g

(d) Virtual pitch, p_v

(e) Standard pitch, p_s

Pitch ratio, p/D

Inflow velocity, V'

Slipstream velocity, V_s

Thrust, T.

Torque, Q.

Power, P.

(If "coefficients" are introduced all units used must be consistent.)

Efficiency $\eta = T\,V/P$.

Revolutions per sec., n; per min., N.

Effective helix angle $\Phi = \tan^{-1}\left(\frac{V}{2\pi rn}\right)$

5. NUMERICAL RELATIONS

1 HP. = 76.04 kg/m/sec = 550 lb./ft./sec.

1 kg/m/sec = 0.01315 HP.

1 mi./hr. = 0.44704 m/sec

1 m/sec = 2.23693 mi./hr.

1 lb. = 0.4535924277 kg

1 kg = 2.2046224 lb.

1 mi. = 1609.35 m = 5280 ft.

1 m = 3.2808333 ft.